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A

DICTIONARY

OF

ELECTRICAL WORDS, TERMS AND PHRASES.

BY

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PREFACE.

The rapid growth of electrical science, and the almost daily addition to it of new words, terms and phrases, coined, as they too frequently are, in ignorance of those already existing, have led to the production of an electrical vocabulary that is already bewildering in its extent. This multiplicity of words is extremely discouraging to the student, and acts as a serious obstacle to a general dissemination of electrical knowledge, for the following reasons:

1. Because, in general, these new terms are not to be found even in the unabridged editions of dictionaries.

2. The books or magazines, in which they were first proposed, are either inaccessible to the ordinary reader, or, if accessible, are often written in phraseology unintelligible except to the expert.

3. The same terms are used by different writers in conflicting senses.

4. The same terms are used with entirely different meanings.

5. Nearly all the explanations in the technical dictionaries are extremely brief as regards the words, terms and phrases of the rapidly growing and comparatively new science of electricity.

In this era of extended newspaper and periodical publication, new words are often coined, although others,

already in existence, are far better suited to express the same ideas. The new terms are used for a while and then abandoned; or, if retained, having been imperfectly defined, their exact meaning is capable of no little ambiguity; and, subsequently, they are often unfortunately adopted by different writers with such varying shades of meaning, that it is difficult to understand their true and exact significance.

Then again, old terms buried away many decades ago and long since forgotten, are dug up and presented in such new garb that their creators would most certainly fail to recognize them.

It has been with a hope of removing these difficulties to some extent that the author has ventured to present this Dictionary of Electrical Words, Terms and Phrases to his brother electricians and the public generally.

He trusts that this dictionary will be of use to electricians, not only by showing the wonderful extent and richness of the vocabulary of the science, but also by giving the general consensus of opinion as to the significance of its different words, terms or phrases. It is, however, to the general public, to whom it is not only a matter of interest but also one of necessity to fully understand the exact meaning of electrical literature, that the author believes the book will be of greatest value.

In order to leave no doubt concerning the precise meaning of the words, terms and phrases thus defined, the following plan has been adopted of giving,

(1) A concise definition of the word, term or phrase.

(2) A brief statement of the principles of the science involved in the definition.

(3) Where possible and advisable, a cut of the apparatus described or employed in connection with the word, term or phrase defined.

It will be noticed that the second item of the plan makes the Dictionary approach to some extent the nature of an Encyclopedia. It differs, however, from an encyclopedia in its scope, as well as in the fact that its definitions in all cases are concise.

Considerable labor has been expended in the collection of the vocabulary, for which purpose electrical literature generally has been explored. In the alphabetical arrangement of the terms and phrases defined, much perplexity has arisen as to the proper catch-word under which to place them. It is believed that part of the difficulty in this respect has been avoided by the free use of cross-references.

In elucidating the exact meaning of terms by a brief statement of the principles of the science involved therein, the author has freely referred to standard text books on electricity, and to periodical literature generally. He is especially indebted to works or treatises by the following authors, viz.: S. P. Thompson, Larden, Cumming, Hering, Prescott, Ayrton, Ayrton and Perry, Pope, Lockwood, Sir Wm. Thomson, Fleming, Martin and Wetzler, Preece, Preece and Sivewright, Forbes, Maxwell, De Watteville, J. T. Sprague, Culley, Mascart and Joubert, Schwendler, Fontaine, Noad, Smee, Depretz, De la Rive, Harris, Franklin, Cavallo, Grove, Hare, Daniell, Faraday and very many others.

The author offers his Dictionary to his fellow electricians as a starting point only. He does not doubt that his book will be found to contain many inaccuracies, ambiguous statements, and possibly doubtful definitions. Pioneer work of this character must, almost of necessity, be marked by incompleteness. He, therefore, invites the friendly criticisms of electricians generally, as to errors of omission and commission, hoping in this way to be able finally to crystallize a complete vocabulary of electrical words, terms and phrases.

The author desires in conclusion to acknowledge his indebtedness to his friends, Mr. Carl Hering, Mr. Joseph Wetzler and Mr. T. C. Martin for critical examination of his proof sheets; to Dr. G. G. Faught for examination of the proofs of the parts relating to the medical applications of electricity, and to Mr. C. E. Stump for valuable aid in the illustration of the book; also to Mr. Geo. D. Fowle, Engineer of Signals of the Pennsylvania Railroad Company, for information concerning their System of Block Signaling, and to many others.

Central High School, Philadelphia, Pa. EDWIN J. HOUSTON.

September, 1889.

A DICTIONARY

OF

ELECTRICAL WORDS, TERMS AND PHRASES.

Abscissas, Axis of——— —One of the *axes of co-ordinates* used for determining the position of points in a curved line.

Thus the position of the point D, Fig. 1, in the curved line O D R, is determined by the vertical distances D 1, and D 2, of such point from two straight lines AB, and AC, called the *axes of co-ordinates.* AC, is called the *axis of abscissas,* and AB, the *axis of ordinates.* A, the point where the lines may be considered as starting or originating, is called the *point of origin.* (See *Co-ordinates, Axes of.*)

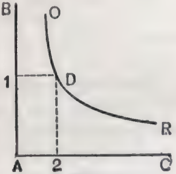


Fig. 1.

Absolute.—Complete in itself.

The terms absolute and relative are used in electricity in the same sense as ordinarily.

Thus, a galvanometer is said to be calibrated *absolutely* when the exact current strengths required to produce given deflections are known; or, in other words, when the *absolute* current strengths are known; it is said to be calibrated *relatively* when only the *relative* current strengths required to produce given deflections are known.

The word absolute, as applied to the units employed in electrical measurements, was introduced by Gauss to indicate the fact that the values of such units are independent both of the size of the instrument employed and of the value of gravity at the particular place where the instrument is used.

The *absolute units of length, mass, and time* are more properly called the C. G. S. units, or *the centimetre-gramme-second units.*

An absolute system of units based on the *milligramme, millimetre,* and *second,* was proposed by Weber, and was called the *millimetre-milligramme-second units.* It has been replaced by the C. G. S. units.

Absolute Calibration.—(See *Calibration, Absolute.*,

Absolute Galvanometer.—(See *Galvanometer, Absolute.*)

Absolute Units.—A term sometimes used to indicate the C. G. S. units, but now generally replaced by the term *centimetre-gramme-second units,* or, more briefly, the C. G. S. units.

Absolute Unit of Current.—A current of ten ampères. (See *Ampère. Units, Practical.*)

Absolute Unit of Electromotive Force.—The one hundred millionth of a volt. (See *Volt. Units, Practical.*)

Absolute Unit of Resistance.—The one thousand millionth of an ohm. (See *Ohm. Units, Practical.*)

Absolute Vacuum.—(See *Vacuum, Absolute*).

Absorption, Electric—— —The apparent soaking of an electric *charge* into the glass or other solid *dielectric* of a Leyden Jar or *Condenser.* (See *Charge. Condenser.*)

The capacity of a condenser, or its ability to hold an electric charge, varies with the time the condenser remains charged. Some of the charge acts as if it *soaked into* the solid dielectric, and this is the cause of the *residual charge.* (See *Charge, Residual.*) Therefore, when the condenser is

discharged, less electricity appears than was passed in; hence the term *electric absorption.*

Absorptive Power.—The property possessed by many solid bodies of taking in and condensing gases within their pores.

Carbon possesses marked absorptive powers. The absorption of gases in this manner by solid bodies is known technically as the *occlusion of gases.* (See *Occlusion of Gases.*)

One volume of charcoal, at ordinary temperatures and pressures, absorbs of

Ammonia	90	volumes
Hydrochloric Acid	85	"
Sulphur Dioxide	65	"
Hydrogen Sulphide	55	"
Nitrogen Monoxide	40	"
Carbonic Acid Gas	35	"
Ethylene	35	"
Carbon Monoxide	9.42	"
Oxygen	9.25	"
Nitrogen	6.50	"
Hydrogen	1.25	"

(*Saussure.*)

Acceleration.—The rate of change of velocity.

Acceleration is thus distinguished from velocity: velocity expresses in time the rate-of-change of position, as a velocity of three metres per second; acceleration expresses in time the rate-of-change of velocity, as an acceleration of one centimetre per second.

Since all matter is inert, and cannot change its condition of rest or motion without the application of some force, acceleration is necessarily due to some force outside of matter itself. A force may therefore be measured by the acceleration it causes in a given mass of matter.

Acceleration is termed *positive* when the velocity is *increasing*. and *negative* when it is *decreasing.*

Acceleration, Unit of————That acceleration which

will give to a body unit-velocity in unit-time; as, for example, one centimetre per second.

Bodies falling freely in a vacuum, and approximately so in air, acquire an acceleration which in Paris or London, at the end of a second, amounts to about 981 centimetres per second, or nearly 32.2 ft. per second.

$A = \frac{V}{T}$, or in other words, *the acceleration equals the velocity divided by the time.*

But, since the velocity equals the Distance, or the Length traversed in a unit of time, $V = \frac{L}{T}$.

Therefore, $A = \frac{V}{T} = \frac{\frac{L}{T}}{\frac{T}{1}} = \frac{L}{T^2}$, or, *the acceleration equals the length,* or the distance passed through, *divided by the square of the time in seconds.*

These formulæ represent the *Dimensions of Acceleration.*

Accumulator, or Condenser.—A term often applied to an apparatus called a Leyden Jar or Condenser, which permits the collection from an electric source of a greater charge than it would otherwise be capable of giving.

The ability of the source to give an increased charge is due to the increased capacity of a plate or other conductor when placed near another plate or conductor. (See *Condenser. Jar, Leyden.*)

Accumulator, Storage or Secondary Cell.—Two inert plates dipping into a liquid incapable of acting chemically on either of them until after the passage of an electric current, when they become capable of furnishing an independent electric current.

This use of the term accumulator is the one most commonly employed. (See *Storage Cells or Accumulators.*)

Accumulator.—A term sometimes applied to Sir Wm. Thomson's *Electric Current Accumulator.*

The copper disc D, Fig. 2, has freedom of rotation, on a horizontal axis at O, in a magnetic field, the lines of force of which, represented by the dotted lines in the drawing, pass down perpendicularly into the plane of the paper.

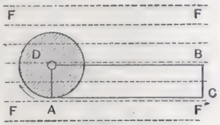


Fig. 2.

If, now, a current from any source be passed in the direction A, O, B, C, A, through the circuit A, O, B, C, A, which is provided with spring contacts at O, and A, the disc will rotate in the direction of the curved arrow. This motion is due to the current acting on that part of the disc which lies between the two contacts—A and O. This apparatus is known as *Barlow's Wheel.*

If, when no current is passing through the circuit, the disc be turned in the direction of the arrow, a current is set up in such a direction as would oppose the rotation of the disc. (See *Lenz's Law.*)

If, however, the disc be turned in the opposite direction to that of the arrow, induction currents will as before be produced in the circuit. As this rotation of the disc tends to move the circuit O A, towards the parallel but oppositely directed circuit B C, these two circuits, being parallel and in opposite directions tend to repel one another, and there will thus be set up induced currents that tend to oppose the motion of rotation, and the current of the circuit will therefore increase in strength. (See *Electro-Dynamics*). Should then a current be started in the circuit, and the original field be removed, the induction will be continued, and a current which, up to a certain extent, increases or accumulates, is maintained in the circuit during rotation of the disc. (*Larden.*)

Barlow's Wheel, when used in this manner, is known as *Thomson's Electric Current Accumulator.*

Accumulator, Water-Dropping——— —An apparatus devised by Sir W. Thomson for increasing the difference of potential of an electric charge.

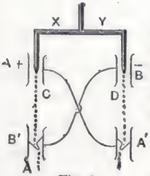


Fig. 3.

The tube X Y, Fig. 3, connects with a reservoir of water which is maintained at the zero potential of the earth. The water escapes from the openings at C and D in small drops and falls on funnels provided, as shown, to receive the separate drops and again discharge them.

The vessels A, A', and B, B', which are electrically connected as shown, are maintained at a certain small difference of potential, as indicated by the respective + and — signs.

Under these circumstances, therefore, C and D, will be charged inductively with charges opposite to those of A and B, or with — and + electricities respectively. As the drops of water fall on the funnels, the charges which the funnels thus constantly receive, are given up to B' and A', before the water escapes. Since, therefore, B, B', and A, A', are receiving constant charges, the difference of potential between them must continually increase. This apparatus operates on the same principle as the replenisher. The drops of water act as the carriers, and A, A', and B, B', as the hollow vessels. (See *Replenisher.*)

Accumulators or Condensers; Laws of Accumulation of Electricity.—Sir W. Snow Harris, by the use of his *Unit-Jar*, and *Electric Thermometer*, deduced the following laws for the accumulation of electricity, which we quote from Noad's "Student's Text-Book of Electricity," revised by Preece:

(1) "Equal quantities of electricity are given off at each revolution of the plate of an electrical machine to an *un-*

charged surface, or to a surface *charged* to any degree of saturation."

(2) "A coated surface receives equal quantities of electricity in equal times; and the number of revolutions of the plate is a fair measure of the relative quantities of electricity, all other things remaining the same."

(3) "The free action of an electrical accumulation is estimated by the interval it can break through, and is directly proportional to the quantity of electricity."

(4) "The free action is inversely proportional to the surface."

(5) "When the electricity and the surface are increased in the same ratio, the discharging interval remains the same; but if, as the electricity is increased, the surface is diminished, the discharging interval is directly as the square of the quantity of electricity."

(6) "The resistance of air to discharge is as the square of the density directly."

According to some later investigations, the quantity a plane surface can receive under a given density depends on the linear boundary of the surface as well as on the area of the surface.

"The amount of electrical charge depends on surface and linear extension conjointly. There exists in every plane surface what may be termed an *electrical boundary*, having an important relation to the grouping or disposition of the electric particles in regard to each other and to surrounding matter. This boundary in circles or globes is represented by their circumferences. In plane rectangular surfaces, it is by their linear extension or perimeter. If this *boundary* be constant, their electrical charge varies with the *square root of the surface*. If the *surface* be constant the charge varies with the *square root of the boundary*. If the surface and boundary both vary, the charge varies with the *square root of the surface multiplied into the square root of the boundary*."

These laws apply especially to continuous surfaces taken as a whole, and not to surfaces divided into separate parts.

By electrical charge Harris meant the quantity sustained on a given surface under a given electrometer indication; by electrical intensity, he meant the indication of the electrometer corresponding to a given quantity on a given surface.

For further information see *Condensers, Capacity of.*

A. C. C.—An abbreviation used in medical electricity for *Anodic Closure Contraction*, or the contraction observed on closing the circuit when the anode is lying over the muscle.

The term *anode* is sometimes, as above, used to indicate the positive terminal of an electric battery or source. (See *Anode.*)

Achromatic.—Free from false coloration.

Images formed by ordinary lenses do not possess the true colors of the object, unless the edges of the lenses are cut off by the use of a diaphragm; *i. e.*, an opaque plate with a circular central opening. The edges of the lenses disperse the light like an ordinary prism, and so produce rainbow-colored (prismatic) fringes in the image. The use of an achromatic lens is to obviate this false coloration.

The ray of light entering the prism A B C, Fig. 4, suffers dispersion (separation into prismatic colors). This dispersion in the same medium is proportional to the angle *g*, between the incident and emergent faces, called the *refracting angle.*

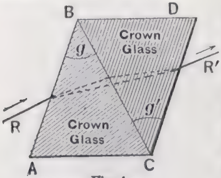


Fig. 4.

If, now, another prism B C D, of the same material, whose refracting angle *g'*, is equal to *g*, is combined with the first prism in the manner shown in Fig. 4, it will produce an equal but opposite dispersion, so that the ray of light will emerge at R, free from rainbow tints, but parallel to its original direction.

The variety of glass called *crown glass* produces only half as great dispersion of light as the variety called *flint glass,* under the same refracting angle *g*. If the prism A B C, of crown glass, Fig. 5, whose angle *g*, is twice as great as the refracting angle *g′*, of the prism B C D, of flint glass, be connected with it in the manner shown, then the ray R, will be transmitted free from color, *but will not emerge parallel to its original direction;* in other words, it suffers refraction or bending. (See *Refraction.*)

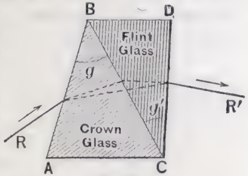


Fig. 5.

The construction of achromatic lenses is based on this principle.

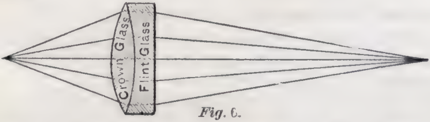


Fig. 6.

The crown glass is generally made with two convex surfaces; the flint glass, with one concave and one plane surface, as shown in Fig. 6.

Sometimes both surfaces of the flint glass are made curved, as in Fig. 7.

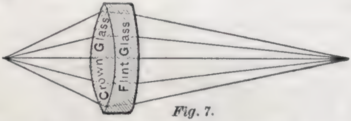


Fig. 7.

Aclinic Line.—The magnetic equator, or a line on the earth's surface connecting places where the magnetic needle has no inclination or dip.

The magnetic equator is not a circle. It cuts the geograph-

ical equator at 2° E. long., and at 170° W. long. (See *Inclination Map or Chart.*)

Acoustic Engraving.—(See *Engraving, Acoustic.*)

Acoustic Telegraph.—A non-recording system of telegraphic communication, in which the dots and dashes of the Morse system, or the deflections of the needle in the needle system, are replaced by sounds that follow one another at intervals that represent the dots and dashes, or the deflections of the needle, and thereby the letters of the alphabet.

Steinheil and Bright each invented acoustic systems of telegraphy in which electro-magnetic bells are used. Morse invented a *Sounder*, for this purpose, which is used very generally. (See *Sounder, Telegraphic.*)

For details of the apparatus and system see *Telegraphy, American or Morse system of.*

Actinic Photometer.—(See *Photometer, Actinic.*)

Actinic Rays.—The rays of light, or other forms of radiant energy that possess the power of effecting *chemical decomposition.* (See *Decomposition.*)

All rays of light, and even some of those invisible to the human eye, are *actinic* to some particular chemical substance or another. Whether the ether waves produce the effects of heat, light, or chemical decomposition depends on the *nature of the material on which they fall, as well as on the character of the waves themselves.*

Actinism.—The chemical effects of light, as manifested in the decomposition of various substances.

Under the influence of the sun's light, the carbonic acid absorbed by the leaves of plants is decomposed in the living leaf into carbon, which is retained by the plant for the formation of its woody fibre or ligneous tissue, and oxygen, which is thrown off.

The bleaching of curtains, carpets, and other fabrics exposed to sunlight is caused by the actinic power of the light. The photographic picture is impressed by the actinic power of

light on a plate covered with some sensitive metallic salt, generally silver.

Action, Local—— —An irregular dissolving or consumption of the zinc or positive element of a voltaic battery, by the fluid or electrolyte, when the circuit is open or broken, as well as when closed, or in regular action.

Local action is due to impurities, such as carbon, iron, arsenic, etc., in the positive plate. These impurities form with the positive element little voltaic couples, and thus direct the corrosive action of the liquid to portions of the plate near the impurities. Local action causes a waste of energy. It may be avoided by amalgamation of the zinc. (See *Zinc, Amalgamation of.*)

Action, Local—— —A term proposed, but not generally adopted, to indicate the wasteful currents in the pole pieces or cores of dynamo-electric machines.

These currents are now generally known as *Eddy, Foucault,* or *Parasitical Currents.* (See *Currents, Eddy, Foucault, Local,* or *Parasitical.*)

Action, Magne-Crystallic—— —(See *Magne-Crystallic Action.*)

Action, Unit of—— —A rate of working, which will perform one unit of work per second.

In C. G. S. units, the activity of one erg per second. This unit is very small. One *Watt,* the practical unit of power, is equal to ten million ergs per second. (See *Watt.*)

The unit of activity generally used for mechanical power is one horse-power, or 746 watts. (See *Horse-power.*)

Activity.—The work done per second by any agent.

Work-per-second, or, as generally termed in the United States, *Power,* or *Rate of Doing Work.* (See *Power.*)

A. D. C.—An abbreviation used in medical electricity for *Anodic Duration Contraction.*

Adhesion.—The attraction that exists between unlike molecules. (See *Attraction, Molecular.*)

Adiathermancy.—Opacity to heat.

A substance is said to be *diathermanous* when it is transparent to heat. Clear, colorless crystals of rock salt are very transparent both to light and to heat. Rock salt, covered with a layer or deposit of lamp-black or soot, is quite transparent to heat. An adiathermanous body is one which is opaque to heat.

Heat transparency varies not only with different substances, but also with the nature of the source from which the heat is derived. Thus, a substance may be opaque to the heat from a non-luminous source, such as a vessel filled with boiling water, while it is comparatively transparent to that from a luminous source, such as an incandescent solid, or the voltaic arc.

A similar difference exists as regards transparency to light. A colorless glass will allow light of any color to pass through it. A blue glass will allow blue light to pass freely through it, but will completely prevent the passage of any red light; and so with other colors.

Æpinus' Condenser.—(See *Condenser.*)

Affinity, Chemical —— — Atomic attractions.

The force that causes atoms to unite and form chemical molecules.

Atomic, or chemical attraction generally results in a loss of the characteristic qualities, or properties, that distinguish one kind of matter from another. In this respect it differs from *adhesion*, or the force which holds unlike molecules together. (See *Adhesion.*) If, for example, sulphur is mixed with lamp-black, no matter how intimate the mixture, the separate particles, when examined by a glass, exhibit their peculiar color, lustre, etc. If, howerer, the sulphur is chemically united with the carbon, a colorless, transparent, mobile liquid, called carbon bisulphide, results, that possesses a disagreeable, penetrating odor.

Chemical affinity, or atomic combination, is influenced by a variety of causes, viz.;

(1) *Cohesion.* Cohesion, by binding the molecules more firmly together, opposes their mutual atomic attractions.

A solid rod of iron will not readily burn in the flame of an ordinary lamp, but if the cohesion be overcome by reducing the iron rod to filings, it burns with brilliant scintillations when dropped into the same flame.

(2) *Solution.* Solution, by imparting to the molecules greater freedom of motion, favors their chemical combination.

(3) *Heat.* Heat favors atomic combination by decreasing the cohesion, and possibly, by altering the electrical relations of the atoms. If too great, heat may produce decomposition. (See *Dissociation.*)

(4) *Light.* Decomposition, or the lessening of chemical affinity through the agency of light, is called *Actinism.* Light also causes the direct *combination* of *substances.* A mixture of equal volumes of hydrogen and chlorine unites explosively when exposed to the action of full sunlight. (See *Actinism.*)

(5) *Electricity.* An electric spark will cause an explosive combination of a mixture of oxygen and hydrogen. Electricity also produces chemical decomposition. (See *Electrolysis.*)

Agone.—A line connecting places on the earth's surface where the magnetic needle points to the true geographical north.

The line of no *declination* or *variation* of a magnetic needle. (See *Declination* or *Variation of Magnetic Needle.*)

As all the places on the earth where the magnetic needle points to the true north may be arranged on a few lines, it will be understood that the pointing of the magnetic needle to the true geographical north is the exception and not the rule. In many places, however, the deviation from the true geographical north is so small that the direction of the needle may be regarded as approximately due north.

Agonic.—Pertaining to the Agone.

Air-Blast.—An invention of Prof. Elihu Thomson to prevent the injurious action of destructive sparking at the commutator of a dynamo-electric machine.

A thin, forcible blast of air is delivered through suitable tubes at points on the three-part commutator cylinder of the Thomson-Houston dynamo, where the collecting brushes bear on its surface. The effect is to blow out the arc and thus prevent its destructive action on the commutator segments. The use of the air-blast also permits the free application of oil, thus further avoiding wear.

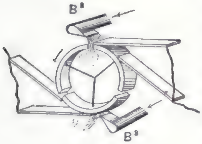


Fig. 8.

The blast-nozzles are shown at B³, B³, Fig. 8, near the collecting brushes.

The air-supply is obtained from a centrifugal blower attached directly to the shaft of the machine. Its construction and operation will be readily understood from an inspection of Fig. 9, in which the top is removed for a ready examination of the interior parts.

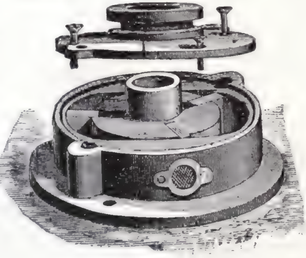


Fig. 9.

Alarms, Electric——— —Various automatic devices by which attention is called to the occurrence of certain events, such as the opening of a door or window; the stepping of a person on a mat or staircase; the rise or fall of temperature beyond a given predetermined point; or to call a person to a telegraphic or telephonic instrument.

Electric alarms are operated by either the closing or the opening of an electric circuit, generally the former, by means of which an electro-magnetic or mechanical bell is rung.

Electric alarms may be divided into two classes, viz. :

1. Mechanically operated alarms, or those operated by clock-work, that is started by means of an electric current.

2. Those in which the alarm is both set into operation and operated by the action of an electric current.

In Fig. 10, is shown the general construction of an electrically started mechanical alarm. The attraction of the armature B, by the electro-magnet A, moves the armature lever pivoted at C, and thus releases the catch *e*, and permits the spring or weight connected with the clock movement to set it in motion and strike the bell.

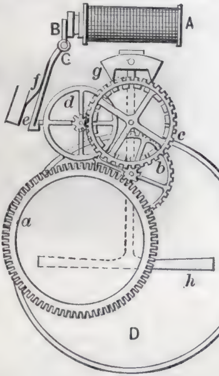


Fig. 10.

Electrically actuated alarm-bells are generally of the automatic make-and-break form. The striking lever is operated by the attraction of the armature of an electro-magnet, and is provided with a contact-point, so placed that when the hammer is drawn away from the bell, on the electro-magnet losing its magnetism, the contact-point is closed, but when it is drawn towards the bell the contact is opened. When, therefore, the hammer strikes the bell, the circuit is opened, and the electro-magnet releases its armature, permitting a spring to again close the contact by moving the striking lever away from the bell. Once set into

action, these movements are repeated while there is battery power sufficient to energize the magnet.

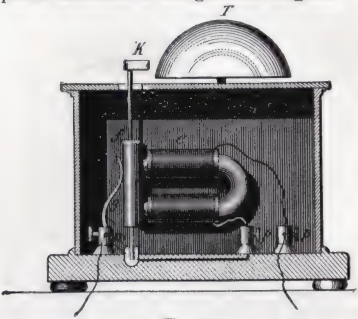


Fig. 11.

In Fig. 11, the battery terminals are connected with the right and left hand binding-posts, P and M. The *hammer* K, is connected with a striking *lever*, which forms part of the circuit, and which is attached to the *armature* of the electro-magnet *e*. A metallic spring *g*, bears against the armature when the latter is away from the magnet, but does not touch the armature when it is moved towards the magnet. The movements of the armature thus automatically open and close the circuit of the electro-magnet.

This form of make-and-break is called an *automatic make-and-break.*

Alarms, Electric Burglar—— —An electric device to automatically announce the opening of a door, window, closet, drawer, or safe, or the passage of a person through a hallway, or on a stairway.

Electric burglar alarm devices generally consist in mechanism for the operation of an automatic make-and-break bell on the closing of an electric circuit. The bell may either continue ringing only while the contact remains closed, or, may, by the throwing on of a local circuit or battery, continue ringing until stopped by some non-automatic device, such as a hand-switch.

The alarm-bell is stationed either in the house when occupied, or on the outside when the house is temporarily vacated, or may connect directly with the nearest police station.

Fig. 12.

Burglar-alarm apparatus is of a variety of forms. Generally, devices are provided by means of which, in case of house protection, an *annunciator* shows the exact part where an entrance has been attempted. (See *Annunciator.*) Switches are provided for disconnecting all or parts of the house from the alarm when so desired, as well as to permit windows to be partly raised for purposes of ventilation without sounding the alarm. A clock is frequently connected with the alarm for the purpose of automatically disconnecting any portion of the house at or for certain intervals of time.

Fig. 12, shows a burglar alarm with annunciator, switches, switch-key, cut-off, and clock.

Alarms, Electric Burglar——Yale Lock Switch for.—An alarm whereby the opening of a door by an authorized party provided with the regular key will not sound an alarm, but any other opening will sound such alarm.

Alarms, Electric Fire or Temperature—— —Instruments for automatically sounding an alarm on an increase of temperature beyond a certain predetermined point.

Fire-alarms are operated by *thermostats*, or by means of mercurial contacts; *i. e.*, a contact closed by the expansion of a column of mercury. (See *Thermostat.*)

In systems of *fire-alarm telegraphs*, the alarm is automatically sounded in a central police station and in the district fire-engine house. (See *Telegraphy, Fire-alarm.*)

The action of mercurial contacts is dependent on the fact that, as the mercury expands by the action of the heat, it reaches a contact-point placed in the tube and thus completes

the circuit through its own mass, which forms the other or movable contact. Sometimes both contacts are placed on opposite sides of a tube and are closed when the mercury reaches them.

Mercurial-temperature or thermostat alarms are employed in hot-houses, incubators, tanks, and buildings, for the purpose of maintaining a uniform temperature.

Alarms, Electric Water or Liquid Level——— —Devices for sounding an alarm electrically when a water surface varies materially from a given level.

An electric bell is placed in a circuit that is automatically closed or broken by the movement of contact-points operated by a change of liquid level.

Alarms, Telegraphic——— —Alarm bells for calling the attention of an operator to a telegraphic instrument when the latter is of the non-acoustic or needle type.

In acoustic systems of telegraphy, the sounds themselves are generally sufficient for this purpose.

Alarms, Telephonic——— —An alarm-bell for calling a correspondent to the telephone.

These alarms generally consist of magneto-electric bells. (See *Magneto-Electric Call-Bell.*)

Alcohol, Electrical Rectification of.——— —A process whereby the bad taste and odor of alcohol, due to the presence of aldehydes, are removed by the electrical conversion of the aldehydes into true alcohols through the addition of hydrogen atoms.

An electric current sent through the liquid, between zinc electrodes, liberates oxygen and hydrogen from the decomposition of the water. The hydrogen converts the aldehydes into alcohol, and deprives the products of their fusel oil, while the oxygen forms insoluble zinc oxide.

Algebraic Notation.—(See *Notation, Algebraic.*)

Alphabet, Telegraphic——— —An arbitrary code consisting of dots and dashes, sounds, deflections of a mag-

netic needle, flashes of light, or movements of levers, following one another in a given predetermined order, to represent the letters of the alphabet and the numerals.

Alphabet, Morse's Telegraphic ——————— Various groupings of dots and dashes, or deflections of a magnetic needle to the right and left, that represent the letters of the alphabet or other signs.

In the Morse alphabet dots and dashes are employed in recording systems, and sounds of varying lengths, corresponding to the dots and dashes in the sounder system.

AMERICAN MORSE CODE.

ALPHABET.

a	- —	n	— -
b	— - - -	o	- -
c	- - -	p	- - - - -
d	— - -	q	- - — -
e	-	r	- - -
f	- — -	s	- - -
g	— — -	t	—
h	- - - -	u	- - —
i	- -	v	- - - —
j	— - — -	w	- — —
k	— - —	x	- — - -
l	——	y	- - - -
m	— —	z	- - - -

& - - - -

NUMERALS.

1	- — — -	6	- - - - - -
2	- - — - -	7	— — - -
3	- - - — -	8	— - - - -
4	- - - - —	9	— - - —
5	— — —	0	——

PUNCTUATION MARKS.

Period	- - — — - -	Interrogation	— - - — -
Comma	- — - —	Exclamation	— — — —

In the *needle telegraph*, the code is similar to that used in the Morse Alphabet. (See *Telegraphy, Single-needle.*)

Alphabet, Telegraphic: Continental Code.

	Printing	Single Needle		Printing	Single Needle
a	.—	\/	n	—.	/\
b	—...	/\\\	o	———	///
c	—.—.	/\/\	p	.——.	\//\
d	—..	/\\	q	——.—	//\/
e	.	\	r	.—.	\/\
f	..—.	\\/\	s	...	\\\
g	——.	//\	t	—	/
h	....	\\\\	u	..—	\\/
i	..	\\	v	...—	\\\/
j	.———	\///	w	.——	\//
k	—.—	/\/	x	—..—	/\\/
l	.—..	\/\\	y	—.——	/\//
m	——	//	z	——..	//\\

Similar symbols are employed for the numerals and the punctuation marks.

It will be observed that it is mainly in the characters of the American Morse, in which spaces are used, that the Continental characters differ from the American. This is due to the use of the needle instrument. A movement or deflection of the needle to the *left* signifies a *dot;* a movement to the right, a dash.

For methods of receiving the alphabet, see *Sounder, Morse*

Telegraphic. Recorder, Morse's. Recorder, Chemical. Recorder, Siphon. Relay or Receiving Magnet.

All-night Arc Lamp.—(See *Double-Carbon Arc Lamp.*)

Alloy.—A combination, or mixture, of two or more metallic substances.

Alloys in most cases appear to be true chemical compounds. In a few instances, however, they may form simple mixtures.

The composition of a few important alloys is here given :

Solder, plumber's ; Tin 66 parts, Lead 34 parts.

Pewter, hard ; Tin 92 parts, Lead 8 parts.

Britannia metal ; Tin 100 parts, Antimony 8 parts, Copper 4 parts, Bismuth 1 part.

German silver ; Copper 50, Zinc 25, Nickel 25 parts.

Type metal ; Lead 80, Antimony 20 parts.

Brass, white ; Copper 65, Zinc 35 parts.

Brass, red ; Copper 90, Zinc 10 parts.

Speculum metal ; Copper 67, Tin 33 parts.

Bell metal ; Copper 78, Tin 22 parts.

Aluminium bronze ; Copper 90, Aluminium 10 parts.

Alloys, Palladium ——— —(See *Palladium Alloys.*)

Allotropy, Allotropic State.—A modification of a substance, in which, without changing its chemical composition, it assumes a condition in which its physical and chemical properties are distinct from those it ordinarily possesses.

Thus the element carbon occurs in three widely different allotropic states, viz.:

(1) As charcoal, or ordinary carbon ;

(2) As graphite, or plumbago ; and

(3) As the diamond.

Alternating Current.—An electric current that alternately flows in opposite directions. (See *Current, Alternating.*)

Alternating Motor.—(See *Motor, Alternating Current.*)

Alternating Dynamo-Electric Machine.—A dynamo-electric machine that furnishes alternating currents, (See *Dynamo-Electric Machine.*)

Alternating System of Distribution.—A system of electric distribution in which lamps, motors, or other electroreceptive devices are operated by means of alternating currents that are sent over the line, but which, before passing through said devices, are modified by apparatus called *converters* or *transformers*. (See *Converter* or *Transformer.*)

For details of the alternating system of distribution, see *Systems of Distribution* by *Alternating Currents.*

Alternatives, Voltaic—— —A term used in medical electricity to indicate sudden reversals of polarity of the electrodes of a voltaic battery.

An alternating current from a voltaic battery, obtained by the use of a suitable commutator.

Sudden reversals of polarity produce more energetic effects of muscular contraction than do simple closures or completions of the circuit.

Since all electricity is one and the same thing or force, whatever its source, the necessity for the term voltaic alternative in place of alternating current is by no means clear. The only consideration that would appear to warrant its continued use is that the alternating currents obtained from the voltaic batteries generally employed in electro therapeutics, by the action of a pole-changer, possess a much smaller electro-motive force than do faradic currents, which are also alternating.

Amalgam.—The combination or mixture of a metal with mercury.

Amalgam, Electric—— —A substance with which the rubbers of the ordinary frictional electric machines are covered.

Electric amalgams are of various compositions. The following is excellent :

Melt together five parts of zinc and three of tin, and gradually pour the molten metal into nine parts of mercury. Shake the mixture until cold, and reduce to a powder in a warm mortar. Apply to the cushion by means of a thin layer of stiff grease.

Mosaic gold, or bisulphide of tin, and powdered graphite, both act as good electric amalgams.

An electric amalgam not only acts as a conductor to carry off the negative electricity, but being highly negative to the glass, produces a far higher electrification than would leather or chamois.

Amalgamation.—The act of forming an amalgam, or effecting the combination of a metal with mercury.

Amalgamation of Zinc Battery Plates.—Covering the surface of the zinc plate of a voltaic cell with a thin layer of amalgam in order to avoid *local action.* (See *Action, Local.*)

For details of process, see *Zinc, Amalgamation of.*

Amber.—A resinous substance, generally of a transparent, yellow color.

Amber is interesting electrically as being believed to be the substance in which the properties of electric attractions and repulsions imparted by friction or rubbing were first noticed. It was called by the Greeks ἤλεκτρον from which the word electricity is derived. This property was mentioned by the Greek, Thales of Miletus, 600 B. C., as well as by Theophrastus.

Amorphous.—Having no definite crystalline form.

Mineral substances have certain crystalline forms, that are as characteristic of them as are the forms of animals or plants. Under certain circumstances, however, they occur without definite crystalline form, and are then said to be amorphous solids.

Ampère.—The practical unit of electric current.

Such a current (or rate of flow or transmission of electricity)

as would pass with an *E. M. F.* of one *volt* through a circuit whose *resistance* is equal to one *ohm*. That is to say, a current of the definite strength that would flow through a circuit of a certain resistance and with a certain electro-motive force. (See *Electro-Motive Force. Volt. Resistance. Ohm.*)

Since the ohm is the practical unit of resistance, and the volt the practical unit of electro-motive force, the ampère, or the practical unit of current, is the current that would flow against unit resistance, under unit pressure or electro-motive force.

To make this clearer, take the analogy of water flowing through a pipe under the pressure of a column of water. That which causes the flow is the *pressure or head*; that which resists the flow is the *friction* of the pipe, which will vary with a number of circumstances. The *rate of flow* may be represented by *so many cubic inches of water per second.*

As the pressure or head increases, the flow increases proportionally; as the resistance increases, the flow diminishes.

Electrically, electro-motive force corresponds to the pressure or head of the water, and resistance to the friction of the water and the pipe. The ampère, which is the *unit rate of flow per second,* may therefore be represented as follows,

viz.: $C = \frac{E}{R}$, as was announced by Ohm in his law. (See *Ohm's Law.*)

This expression signifies that C, the *current* in *ampères,* is equal to E, the *electro-motive force* in *volts,* divided by R, the *resistance* in *ohms.*

We measure the rate of flow of liquids as so many *cubic inches* or *cubic feet per second*—that is, in units of quantity. We measure the rate of flow of electricity as so much electricity per second. The electrical unit of quantity is called the *Coulomb.* (See *Coulomb.*) The coulomb is such a quantity as would pass in one second through a circuit in which the rate of flow is one ampère.

An *ampère per second* is therefore equal to *one coulomb.*

The electro-magnetic unit of current is such a current that, passed through a conducting wire bent into a circle of the radius of one centimetre, would attract a unit *magnetic pole* held at its centre, and sufficiently long to practically remove the other pole from the influence, with unit force, *i.e.*, the force of one *dyne.* (See *Dyne.*) The ampère, or practical electro-magnetic unit, is *one-tenth* of *such a current* ; or, in other words, the *absolute unit of current* is ten ampères.

An ampère may also be defined by the chemical decomposition the current can effect as measured by the quantity of hydrogen liberated, or metal deposited.

Defined in this way, an ampère is such a current as will deposit .00032959 grammes, or .005084 grains, of copper per second on the plate of a copper *voltameter* (See *Voltameter*), or which will decompose .00009326 grammes, or .001439 grains, of dilute sulphuric acid per second, or pure sulphuric acid at 59° F. diluted with about fifteen per cent. of water, that is, dilute sulphuric acid of Sp. Gr. of about 1.1.

Ampère-Hour, Ampère-Minute, Ampère-Second.—One ampère flowing for one hour, one minute, or one second respectively.

The ampère-hour is in reality a unit of quantity like the *coulomb.* It is used in the service of electric currents, and is equal to the product of the current delivered, by the time during which it is delivered. The ampère-hour is not a measure of energy, but when combined with the volt, and expressed in *watt-hours*, it is a measure of energy.

The storing capacity of accumulators is generally given in ampère-hours. The same is true of primary batteries.

One coulomb = .0002778 ampère-hours.

One ampère-hour = 3,600 *coulombs.* (See *Watt-Hour, Watt-Minute, Watt-Second.*)

Ampère-Meter ; Am-meter.—A form of *galvanometer* originally designed by Ayrton and Perry to indicate directly,

the strength of current passing in ampères. (See *Galvanometer.*)

Like all galvanometers, the strength of current passing, *i. e.*, the number of ampères, is indicated by the deflection of a magnetic needle placed inside or over a coil of insulated wire through which the current to be measured is passed.

In the form originally devised by Ayrton and Perry, the needle came to rest almost immediately, or was *dead beat* in action. (See *Dead Beat.*) It moved through the field of a permanent magnet. The instrument was furnished with a number of coils of insulated wire, which could be connected either in *series* or in *multiple-arc* by means of a *commutator*, thus permitting the scale reading to be verified or calibrated by the use of a *single* voltaic cell. (See *Circuits, Varieties of. Commutator. Calibration, Absolute or Relative, of Instrument.*) In this case the coils were turned to series, and the plug to the left pulled out, thus introducing a resistance of one ohm.

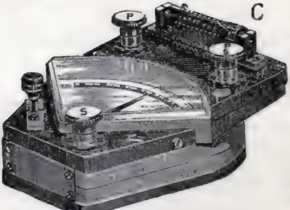


Fig. 13.

Fig. 13, represents a form of Ayrton and Perry's Ammeter. A device called a *commutator* for connecting the coils either in series or parallel is shown at C. Binding-posts are provided at P, PS, and S. The dynamo terminals are connected at the posts P, P, and the current will pass only when the coils are in multiple, thus avoiding accidental burning of the coils. In this case the entire current to be measured passes through the coils so coupled. The posts S, and PS are for connecting the single battery cell current.

A great variety of ampère-meters, or am-meters, have been

devised. They are nearly all, however, constructed on essentially the same general principles.

Ampère-Feet.—The product of the current in ampères by the distance in feet through which that current passes.

It has been suggested that the term ampère-feet should be employed in expressing the strength of electro-magnetism, in the field magnets of dynamo-electric machines or other similar apparatus.

Ampère-Turns, or Ampère-Windings.—A single turn or winding through which one ampère passes.

The number of ampères multiplied by the number of windings or turns of wire in a coil give the total number of ampere-turns in the coil. The magnetism developed by a given number of ampère-turns is independent of the current or of the number of turns of wire, as long as the product of the ampères and the turns remains the same. That is to say, the same amount of magnetism can be obtained by the use of many windings and a small current, as in *shunt dynamos*, or by a few turns and a proportionally large current, as in *series dynamos*. (See *Dynamo-Electric Machines.*)

Ampère-Volt.—A watt, or $\frac{1}{746}$ of a horse-power.

This term is generally written *volt-ampère*. (See *Volt-Ampère.*)

Amperian Currents.—The electric currents that are assumed in the Amperian theory of magnetism to flow around the molecules of a magnet. (See *Magnetism, Amperian Theory or Hypothesis of.*)

The Amperian currents are to be distinguished from the *Eddy, Foucault, or Parasitical Currents,* since, unlike them, they are directed so as to produce useful effects. (See *Currents, Eddy, Foucault, Parasitical.*)

Amplitude of Vibration or Wave.—The ratio that exists in any sound-wave between the degree of condensation and rarefaction of the air or other medium in which the wave is propagated.

The amplitude of a wave is dependent on the amount of energy charged on the medium in which the vibration or wave is produced.

A vibration or wave is a to-and-fro motion produced in an elastic material or medium by the action thereon of energy. Sound, light and heat are effects produced by the action of vibrations or waves, which, in the case of sound, are set up in the air, and, in that of light and heat, in a highly tenuous medium called the luminiferous ether.

As the amplitude of a sound wave increases, the loudness or intensity of the sound increases. As the amplitude of the ether-wave increases, the brilliancy of the light or the intensity of the heat increases.

Let A C, Fig. 14, represent an elastic cord or string tightly stretched between A and C. If the string be plucked by the finger, it will move to and fro, as shown by the dotted lines. Each to-and-fro motion is called a *vibration*. The vertical

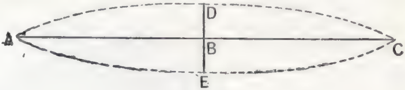


Fig. 14.

distance B D, or B E, represents the *amplitude* of the vibration, and the sound produced is louder, the greater the amount of energy with which the string has been plucked, or, in other words, the greater the value of B D, or B E.

Vibrations assume various forms in solid or fluid media, but in all cases the amplitude will be proportional to the amount of energy that causes the vibration.

Analogous Pole.—(See *Pole, Analogous.*)

Analysis.—The determination of the composition of a compound substance by separating it into the simple substances of which it is composed.

Chemical analysis is *qualitative* when it simply ascertains

the kinds of elementary substances present. It is *quantitative* when it ascertains the relative proportions in which the different components enter into the compound.

Analysis, Electric ——— —Ascertaining the composition of a substance by electrical means.

Various processes have been proposed for electric analysis; they consist essentially in decomposing the substance by means of electric currents, and are either qualitative or quantitative. (See *Electrolysis,* or *Electrolytic Decomposition.*)

Anelectrotonus.—In electro therapeutics, the decreased functional activity that occurs in a nerve in the neighborhood of the anode, or positive electrode. (See *Electrotonus.*)

Angle.—The deviation in direction between two lines.

Angles are measured by arcs of circles. The angle at B A C, Fig. 15, is the deviation of the straight line A B from A C. In reading the lettering of an angle the letter placed in the middle indicates the angle referred to. Thus B A C, means the angle between A B and A C; B A D, the angle between B A and A D. Angles are valued in degrees, there being 360 degrees in an entire circumference or circle. Degrees are indicated thus: 90°, or ninety degrees.

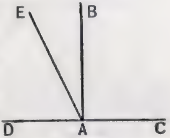


Fig. 15.

The *complement of an angle* is what the angle needs to make its value 90°, or a right angle. Thus B A E, is the complement of the angle E A D, since B A E + E A D = 90°.

The supplement of an angle is what the angle needs to make its value 180°, or two right angles. Thus E A C is the supplement of E A D, because E A D + E A C = 180°, or two right angles.

Angle of Declination or Variation.—The angle

which measures the deviation of the magnetic needle from the east or west of the true geographical north.

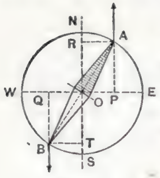


Fig. 16.

Thus, in Fig. 16, if N S represents the true north and south line, the angle of declination is N O A, and the *sign of the variation is east*, because the deviation of the needle is toward the east. For further details see *Declination or Variation of Magnetic Needle.*

Angle of Dip or Inclination.—The angle which a magnetic needle, free to move in a vertical and horizontal plane, makes with a horizontal line passing through its point of support.

A magnetic needle supported at its centre of gravity, and capable of moving freely in a vertical as well as in a horizontal plane, does not retain a horizontal position at all parts of the earth's surface.

The angle which marks its deviation from the horizontal position is called the *angle of dip* or *inclination.* For further details see *Dip, Magnetic.*

Angle of Lag.—The angle through which the axis of magnetism of the armature of a dynamo-electric machine is shifted by reason of the resistance its core offers to sudden reversals of magnetization.

A bi-polar armature of a dynamo-electric machine, has its magnetism reversed twice in every rotation. The iron of the core resists this magnetic reversal. The result of this resistance is to shift the axis of magnetization in the direction of rotation. The angle through which the axis has thereby been shifted is called the *angle of lag.* This term, *angle of lag,* is sometimes incorrectly applied so as to include a similar result produced by the magnetization due to the armature current itself. It is this latter action which, in armatures with soft

iron cores, is the main cause of the angle of lead. (See *Angle of Lead. Lead of Brushes.*)

Angle of Lead.—The angular deviation from the normal position which must be given to the collecting brushes on the commutator cylinder of a dynamo-electric machine, in order to avoid destructive burning. (See *Burning at Commutator.*)

The necessity for giving the collecting brushes a lead, arises both from the magnetic lag, and the distortion of the field of the machine by the magnetization of the armature current. The angle of lead is, therefore, equal to the sum of the *angle of lag* and the *angular distortion due to the magnetization produced by the armature current.*

Angular Velocity.—The velocity of a body moving in a circular path, measured, not, as usual, by the length of its path divided by the time, but by the angle that path subtends times the length of the radius, divided by the time.

If r is the radius, a the angle, and t the time, then

$$\text{Angular Velocity} = \frac{ra}{t}.$$

Unit Angle is that angle subtended by a part of the circumference equal to the length of the radius, or $57^\circ\ 17'\ 44''.8$ nearly (Daniell).

Unit Angular Velocity is the velocity under which a particle moving in a circular path whose radius equals unity would traverse unit angle in unit time.

Animal Electricity.—Electricity produced during life in the bodies of certain animals, such as the Torpedo, the Gymnotus, and the Silurus.

Some of these animals, when of full size, are able to give very severe shocks, and use this curious power as a means of defence against their enemies.

All animals probably produce electricity. If the spinal cord of a recently killed frog be brought into contact with the muscles of the thigh, a contraction will ensue (Matteucci).

The nerve and muscle of a frog, connected by a water contact with a sufficiently delicate galvanometer, show the presence of a current that may last several hours. Du Bois-Reymond showed that the *ends* of a section of muscular fibres are negative, and their *sides* positive, and has obtained a current by suitably connecting them.

All muscular contractions apparently produce electric currents.

Anion.—The electro-negative radical of a molecule.

Literally, the term *ion* signifies a group of wandering atoms. An *anion* is that group of atoms of an electrically decomposed or *electrolysed* molecule which appears at the *anode*. (See *Electrolysis. Anode.*)

As the anode is connected with the electro-positive terminal of a battery or source, the *anion is the electro-negative radical* or *group of atoms, and therefore appears at the electro-positive terminal.* A kathion, or electro-positive radical, appears at the kathode, which is connected with the electro-negative terminal of the battery. Oxygen and chlorine are anions. Hydrogen and the metals are kathions.

Anisotropic Conductor.—A conductor which, though homogeneous in structure like crystalline bodies, has different physical properties in different directions, just as crystals have different properties in the direction of the different crystalline axes.

Anisotropic conductors possess different powers of electric conduction in different directions. They differ in this respect from *isotropic conductors.* (See *Isotropic Conductor.*)

Anisotropic Medium.—A medium, homogeneous in structure like crystalline bodies, possessing different powers of *specific inductive capacity* in different directions.

The term is used to distinguish it from an *isotropic medium.* (See *Isotropic Medium.*)

Anode.—The conductor or plate of a decomposition cell

connected with the positive terminal of a battery, or other electric source.

That terminal of an electric source *out of which* the current flows into the liquid of a decomposition cell or voltameter is called the *anode.* That terminal of an electric source into which the current flows *from* a decomposition cell or voltameter is called the *kathode,*

The anode is connected with the carbon or positive terminal of a voltaic battery, and the kathode with the zinc, or negative terminal. Therefore the word anode has been used to signify the positive terminal of an electric source, and kathode, the negative terminal, and in this sense is employed generally in electro therapeutics. It is preferable, however, to restrict the words anode and kathode to those terminals of a source at which electrolysis is taking place.

The terms anode and kathode in reality refer to the electro-receptive devices through which the current flows. Since it is assumed that the current flows out of a source from its positive pole or terminal, and back to the source at its negative pole or terminal, that pole of any device connected with the positive pole of a source is the part by or at which the current enters, and that connected with the negative pole, the part at which it leaves. Hence, probably, the change in the use of the words already referred to.

Since the *anion,* or the *electro-negative* radical, appears at the *anode,* it is the anode of an *electro-plating bath,* or the plate connected with the positive terminal of the source that is dissolved.

When the term *anode* was first proposed by Faraday, voltaic batteries were the only available electric source, and *the term referred only to the positive terminal of a voltaic battery when placed in an electrolyte.*

Anodic Opening Contraction.—The muscular contraction observed on the opening of a voltaic circuit, the anode of which is placed over a nerve, and the kathode at some other part of the body.

This term is generally written A. O. C. When the anode is placed over a nerve and a weak current is employed, if the circuit be kept closed for a few minutes, it will be noticed that, on opening, the contraction will be much greater than if it had been opened after being closed for only a few seconds. The effect of the A. O. C. therefore depends not only on the current strength but also on the time during which the current has passed through the nerve.

Annunciator, Electro-Magnetic———An electric device for automatically indicating the places at which one or more electric contacts have been closed.

Annunciators are employed for a variety of purposes. In hotels they are used for indicating the number of a room the occupant of which desires some service which he signifies by pushing a button, thus closing an electric circuit. This is indicated or announced on the annunciator by the falling of a *drop* on which is printed a number corresponding with the room, and the ringing of a bell to notify the attendant. The number is released by the action of the armature of an electro-magnet. The drops are replaced in their former position by some mechanical device operated by the hand. In the place of a drop a needle is sometimes used, which points to the number signalling, by the attraction of the armature of an electro-magnet.

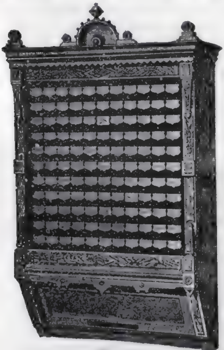


Fig. 17.

Annunciators for houses, burglar-alarms, fire-alarms, elevators, etc., are of the same general construction.

Fig. 17, shows an annunciator suitable for use in hotels.

The numbers 28 and 85 are represented as having been dropped by the closing of the circuit connected with them.

Anomalous Magnet.—A magnet possessing more than two free poles.

There is no such thing as a unipolar magnet. All magnets have two poles. Sometimes, however, several magnets are so grouped that there appear to be more than two poles in the same magnet.

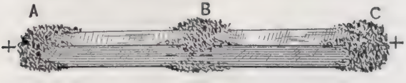


Fig. 18.

Thus, in Fig. 18, the magnet A B C appears to possess three poles, two positive poles at A and C, and a central negative pole at B.

It is clear, however, that the central pole is in reality formed of two juxtaposed negative poles, and that A B C actually consists of two magnets with two poles to each.

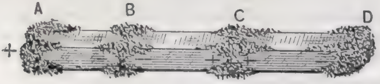


Fig. 19.

The magnet A B C D, Fig. 19, which in like manner appears to possess four separate poles, in reality is formed of three magnets with two poles to each.

Since unlike magnetic poles neutralize each other, it is clear that only similar poles can thus be placed together in order to produce additional magnet poles.

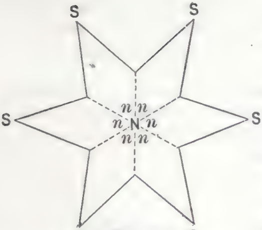


Fig 20

The six-pointed star shown in Fig. 20, is an anomalous magnet with apparently seven poles. The formation of the central N-pole, as is evident from an inspection of the drawing, is due to the six separate north poles, *n*, *n*, *n*, *n*, *n*, *n*, of the six separate magnets S*n*, S*n*, etc. Such a magnet would be formed by touching the star at the point N with the S-pole of a sufficiently powerful magnet.

These extra poles are sometimes called *consequent poles.* Their presence may be shown by means of a compass needle, or by rolling the magnet in iron filings, which collect on the poles.

Anti-Induction Conductor.—A conductor so constructed as to avoid injurious inductive effects from neighboring telegraphic or electric light and power circuits.

Such anti-induction conductors generally consist of a conductor and a metallic shield surrounding the conductor, which is supposed to prevent induction taking place in the wire itself.

The anti-induction conductor sometimes consists of a conductor enclosed by some form of metallic shield, which is supposed to prevent the action of electrostatic induction.

Antilogous Pole.—(See *Pole, Antilogous.*)

Anvil.—The front contact of a telegraphic key that limits its motion in one direction. (See *Telegraphic Key.*)

A. O. C.—A contraction used in medical electricity for *Anodic Opening Contraction.* (See *Anodic Opening Contraction.*)

Apparatus, Interlocking— —(See *Interlocking Apparatus. Block System for Railroads.*)

Arago's Disc.—(See *Disc, Arago's.*)

Arc Lamp, Electric——— —(See *Lamp, Arc, Electric.*)

Arc, Metallic——— —A voltaic arc formed between metallic electrodes.

When the voltaic arc is formed between metallic electrodes instead of carbon electrodes, a flaming arc is obtained, the color of which is characteristic of the burning metal; thus copper forms a brilliant green arc. The metallic arc, as a rule, is much longer than an arc with the same current taken between carbon electrodes.

Arc Micrometer.—(See *Micrometer, Arc.*)

Arc, Voltaic——— —The brilliant arc or bow of light that appears between the carbon electrodes or terminals of a sufficiently powerful source of electricity.

The source of light in the electric arc lamp.

It is called the voltaic arc because it was first obtained by the use of the battery invented by Volta. The term arc was given to it from the shape of the luminous *bow* or *arc* formed between the carbons.

To form the voltaic arc the carbon electrodes are first placed in contact and then gradually separated. A brilliant arc of flame is formed between them, which consists mainly of volatilized carbon. The electrodes are therefore consumed, first, by actual combination with the oxygen of the air, and, second, by volatilization under the combined influence of the electric current and the intense heat.

As a result of the formation of the arc, a tiny crater is formed in the end of the positive carbon, and appears to mark the point out of which the greater part of the current flows.

The crater is due to the greater volatilization of the electrode at this point than elsewhere. It marks the position of greatest temperature of the electrodes, and is the main source of the light of the arc. When, therefore, the voltaic arc is employed for the purposes of illumination with vertically op-

posed carbons, the positive carbon should be made the upper carbon, so that the focus of greatest intensity of the light may be favorably situated for illumination of the space below the lamp.

Fig. 21.

The crater in the end of the positive carbon is seen in Fig. 21. On the opposed end of the negative carbon a projection or nipple is formed by the deposit of the electrically volatilized carbon. The rounded masses or globules that appear on the surface of the electrodes are due to deposits of molten foreign matters in the carbon.

The carbon, both of the crater and its opposed nipple, is converted into pure, soft graphite.

Arc, Voltaic —— Resistance of.—The resistance offered by the voltaic arc to the passage of the current.

Like all conductors, the ohmic resistance of the arc increases with its length, and decreases with its area of cross-section. An increase of temperature decreases the resistance of the voltaic arc.

The total apparent resistance of the voltaic arc is composed of two parts, viz. :

(1.) The true ohmic resistance. (See *Ohmic* or *True Resistance.*)

(2.) The counter electro-motive force, or spurious resistance. (See *Spurious Resistance.*)

Areometer or Hydrometer.—An instrument for determing the specific gravity of a liquid.

A common form of hydrometer consists, as shown in Fig. 22, of a closed glass tube, provided with a bulb, and filled at the lower end with mercury or shot. When placed in different

Fig. 22.

liquids, it floats with part of the tube out of the liquid. The lighter the liquid the smaller is the portion that remains out of the liquid when the instrument floats. The specific gravity is determined by observing the depth to which it sinks when placed in different liquids, as compared with the depth it sinks when placed in water.

Argand Lighter, Electric—— —An electric device for lighting the gas by pulling a pendant B, Fig. 23, after it is turned on by hand.

The gas is ignited by means of an electric spark obtained from the *extra current* of a *spark coil.* (See *Current, Extra*).

Argand Valve Burner, Electric—— —A burner in which the pulling of the ball B, Fig. 24, turns on and lights the gas, while the motion of the slide extinguishes it.

In some forms of argand burner, a second pulling of the ball B, turns off the gas.

Fig. 23.

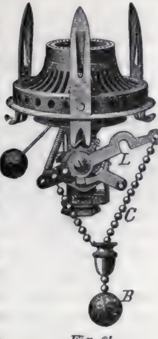


Fig. 24.

Armature. — A mass of iron or other magnetizable material placed on or near the pole or poles of a magnet.

In the case of a *permanent magnet* the armature, when used as a *keeper*, is of soft iron and is placed directly on the magnet poles. In this case it preserves or keeps the magnetism by closing the *lines of magnetic force* of the

magnet through the soft iron of the armature, and is then called a *keeper*. In the case of an electro-magnet, the armature is placed near the poles, and is moved toward them whenever the magnet is energized by the passage of the current. This movement is made against the action of a spring or weights, so that on the loss of magnetism by the magnet, the armature moves in the opposite dlrection. (See *Magnet, Permanent. Keeper of Magnet.*)

When the armature is of soft iron it moves towards the magnet on the completion of the circuit through the coils, no matter in what direction the current flows, and is then called a *non-polarized armature*. When made of *steel*, or of another electro-magnet, it moves towards or from the poles, according to whether its poles are of the same or of different polarity. Such an armature is called a *polarized armature*. (See *Armature, Polarized.*)

Armature, Dynamo—— —The part of a dynamo-electric machine in which the useful currents are generated.

The armature usually consists of a series of coils of insulated wire or conductors, that are wrapped around or grouped on a central core of iron. The movement of these wires or conductors through the magnetic field of the machine produces an electric current by means of the *electro-motive forces* so generated. Sometimes the field is rotated; sometimes both armature and field rotate.

The armatures of dynamo-electric machines are of a great variety of forms. They may for convenience be arranged under the following heads, viz.:

Cylindrical or drum armatures, disc armatures, pole or radial armatures, ring armatures, and spherical armatures. For further particulars see above terms. Armatures are also divided into classes according to the character of the magnetic field through which they move—into uni-polar, bi-

polar, and multi-polar armatures. (See *Dynamo-Electric Machines.*)

The term armature as applied to a dynamo-electric machine was derived from the fact that the iron core acts to magnetically connect the two poles of the field magnets as an ordinary armature does the poles of a magnet.

Armatures of Holtz Machine.—A badly chosen term for the pieces of paper on the stationary plate of the Holtz and other similar machines.

Armature, Polarized ——— —An armature that possesses a polarity independent of that imparted by the magnet pole near which it is placed.

In permanent magnets the armatures are made of soft iron, and therefore, by *induction*, become of a polarity opposite to that of the magnet poles that lie nearest them. They have, therefore, only a motion of attraction towards such poles. (See *Induction, Magnetic.*)

In electro-magnets the armatures may either be made of soft iron, in which case they are attracted only on the passage of the current; or they may be formed of permanent steel magnets, or may be electro-magnets themselves, in which case the passage of the current through the coils of the electro-magnet or electro-magnets may cause either attraction or repulsion according as the adjacent poles are of opposite polarity or are of the same polarity.

Armature Coils, Dynamo ——— —The coils of wire or conductors on the armature of a dynamo-electric machine. (See *Dynamo-Electric Machine, Armature Coils.*)

Armature Core, Dynamo ——— —The core of iron around or on which the armature coils are wound or disposed. (See *Dynamo-Electric Machine, Armature Cores.*)

Armor of Cable.—The protecting sheathing or metallic covering on the outside of a submarine or other electric cable.

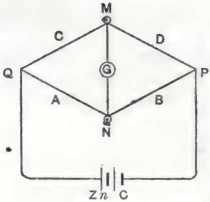


Fig. 25.

Arms of Bridge or of Electric Balance.—The electric resistances in an apparatus for the measurement of resistance, known as Wheatstone's Balance or Bridge.

An unknown resistance, such for example, as that at D, Fig. 25, is measured by so proportioning the known resistances A, C, and B, that no current flows through the galvanometer G, across the circuit or bridge M G N. (See *Balance, Wheatstone's Electric.*)

Arms or Brackets, Telegraphic ——— —Arms or brackets placed on telegraph poles for the support of the insulators. (See *Brackets or Arms, Telegraphic.*)

Arrester, Lightning ——— —A device for protecting instruments on any line from disturbance by lightning. (See *Lightning Arrester.*)

Artificial Carbons.—(See *Carbons, Artificial.*)

Artificial Illumination.—(See *Illumination, Artificial.*)

Artificial Magnets.—Any magnet not formed naturally. All magnets other than magnetic iron ore, or lodestone, or meteoric iron. (See *Magnets, Artificial.*)

Articulate Speech.—The successive tones of the human voice that are necessary to produce intelligible words.

The phrase articulate speech refers to the joining or articulation of the successive sounds involved in speech. The receiving diaphragm of a telephone is caused to reproduce the articulate speech uttered near the transmitting diaphragm.

Asphyxia.—Suspended respiration, resulting eventually in death, from the non-aeration of the blood.

In cases of insensibility by an electric shock a species of asphyxia is sometimes brought about. This is due, probably, to the failure of the nerves and muscles that carry on respira-

tion. The exact manner in which death by electrical shock results is not known. (See *Death, Electrical.*)

Astatic Circuits.—(See *Circuits, Astatic.*)

Astatic Needle.—A magnetic needle consisting of two magnets rigidly connected together and placed parallel and directly over each other, with opposite poles opposed.

An astatic needle is shown in Fig. 26. The two magnets N S, and S′ N′, are directly opposed in their polarities, and are rigidly connected together by means of the axis *a a*. So disposed, the two magnets act as a very weak single needle when placed in a magnetic field.

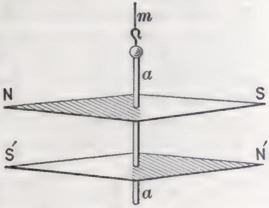


Fig. 26.

Were the two magnets N S, and S′ N′, of exactly equal strength, with their poles placed in exactly the same vertical plane, they would completely neutralize each other, and the needle would have no directive tendency. Such a system would form an *Astatic Pair* or *Couple.*

In practice it is impossible to do this, so that the needle has a directive tendency, which is often east and west.

The cause of the east and west directive tendency of an unequally balanced astatic system will be understood from an inspection of Fig. 27, *a*. Unless the two needles, *n s*, and *s′n′*, are exactly opposed, they will form a single short magnet, N N N N, S S S S, the poles of which are on the sides of the needle. The system pointing with its sides due N. and S. will appear to have an east and west direction.

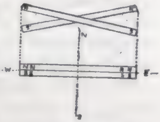


Fig. 27, a.

An astatic needle possesses the valuable property of requiring a smaller force to deflect it than a single needle with

more powerful poles. Its magnetism is not as easily lost or reversed as that of a weaker magnet.

The principal use of the astatic needle is in the *astatic galvanometer*, in which the needle is deflected by the passage of an electric current through a conductor placed near the needle. Therefore it is evident that one of the needles must be outside and the other inside the coil. In the most sensitive form of galvanometer there is also a coil surrounding the upper needle, the two coils being oppositely connected, so that the deflection on both needles is in the same direction, and the deflecting power is equal to the sum of the two coils, while the directive power of the needles is the difference of their magnetic intensities.

In the astatic system, shown in Fig. 27, the current, entering at + and flowing out at —, flows above one needle, S N, and below the other, S′ N′, and therefore deflects both in the same direction, since their poles point in opposite directions.

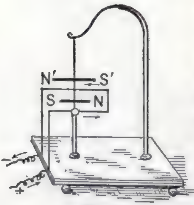


Fig. 27.

In some galvanometers a varying degree of sensitiveness is obtained by means of a magnet, called a *compensating magnet* placed on an axis above the magnetic needle. As the compensating magnet is moved towards or away from the needle the effect of the earth's field is varied, and with it the sensitiveness of the galvanometer. Such a magnet may form with the needle an astatic system. (See *Compensating Magnet.*)

(See *Galvanometer, Astatic. Galvanometer, Mirror. Multiplier, Schweigger's*).

Astatic Galvanometer.—(See *Galvanometer, Astatic.*)

Astatic System.—A term applied to an astatic combination of magnets.

Asymptote.—A curved line that continually approaches a straight line but never meets it.

In Fig. 28, the asymptote C D continually approaches the line *y z*, but never meets it.

This mathematical conception is like a value which, although constantly reduced to one-half of its former value, is nevertheless never reduced to *zero* or *no value*.

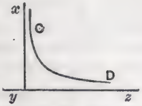


Fig. 28.

Atmosphere, The—— —The ocean of air that surrounds the earth.

The atmosphere is composed, by weight, of oxygen 23 parts, nitrogen 77 parts, carbonic acid gas from 4 to 6 parts in 10,000 (or about a cubic inch of carbonic acid to a cubic foot of air), together with varying proportions of the vapor of water.

Besides these constant ingredients there are in most localities a number of other substances present as impurities.

Atmosphere, An—— —A pressure of a gas or fluid equal to about 15 pounds to the square inch.

At the level of the sea the atmosphere exerts a pressure of about 15 pounds avoirdupois on every square inch of the earth's surface. This has therefore been taken as a unit of fluid pressure.

For more accurate measurements pounds to the square inch are employed.

Atmospheric pressures are measured by instruments called *Manometers*. (See *Manometer*.)

Atmosphere, Residual—— —The trace of air or other gas remaining in a space which has been exhausted of its gaseous contents by a pump or other means.

It is next to impossible to remove all traces of air from a vessel by any known form of pump or other appliance. (See *Vacuum, Absolute*.)

Atmospheric Electricity.—The free electricity almost always present in the atmosphere.

The free electricity of the atmosphere is generally positive, but often changes to negative on the approach of fogs and

clouds. It exists in greater quantity in the higher regions of the air than near the earth's surface. It is stronger when the air is still than when the wind is blowing. It is subject to yearly and daily changes in its intensity, being stronger in winter than in summer, and at the middle of the day than either at the beginning or the close.

Atmospheric Electricity, Origin of————The exact cause of the free electricity of the atmosphere is unknown.

Peltier ascribes the cause of the free electricity of the atmosphere to a negatively excited earth, which charges the atmosphere by *induction*. (See *Induction, Electrostatic.*) It has been ascribed to the evaporation of water; to the condensation of vapor; to the friction of the wind; to the motion of terrestrial objects through the earth's magnetic field; to induction from the sun and other heavenly bodies; to differences of temperature; to combustion, and to gradual oxidation of plant and animal life. It is possible that all these causes may have some effect in producing the free electricity of the atmosphere.

Whatever the cause of the free electricity of the atmosphere, there can be but little doubt that it is to the condensation of aqueous vapor that the high *difference of potential* of the lightning flash is due. (See *Difference of Potential.*) As the clouds move through the air they collect the free electricity on the surfaces of the minute drops of water of which clouds are composed, and when many thousands of these subsequently collect in larger drops the difference of potential is enormously increased in consequence of the equally enormous decrease in the surface of the single drop over the sum of the surfaces of the coalescing drops.

Atom.—The smallest quantity of elementary or simple matter that can exist.

The ultimate particle of matter.

Atom means that which cannot be cut. It is generally

agreed, that material atoms are absolutely unalterable in size, shape, weight and density; that they can neither be cut, scratched, flattened, nor distorted; and that they are unaffected in size, density, or shape, by heat or cold, or by any known physical force.

Although almost inconceivably small, atoms nevertheless possess a definite size and mass. According to Sir Wm. Thomson, the smallest visible organic particle, 1-4000 of a millimetre in diameter, will contain about 30,000,000 atoms.

Atom, Gramme ——— —Such a number of grammes of any elementary substance as is numerically equal to the atomic weight of the substance.

The gramme-atom of a substance represents the number of *calories*, required to raise the temperature of one gramme of that substance through 1° C. (See *Heat, Atomic. Calorie.*)

Atomic Attraction.—The attraction that causes the atoms to combine. (See *Affinity, Chemical.*)

Atomic Energy.—(See *Energy, Atomic.*)

Atomic Heat.—(See *Heat, Atomic.*)

Atomicity.—The combining capacity of the atoms.

The relative equivalence of the atoms or their *atomic capacity.*

The elementary atoms do not always combine atom for atom. Some single atoms of certain elements will combine with two, three, four, or even more atoms of another element.

The value of the atomic capacity of an atom is called its *quantivalence* or *valency.*

Elements whose atomic capacity is—

One,	are called	Monads,	or	Univalent.
Two,	" "	Dyads,	"	Bivalent.
Three,	" "	Triads,	"	Trivalent.
Four,	" "	Tetrads,	"	Quadrivalent.

Five,	are called	Pentads,	or Quinquivalent.
Six,	" "	Hexads,	" Sexivalent.
Seven,	" "	Heptads,	" Septivalent.

Atomic Weight.—The relative weights of the atoms of elementary substances.

Since the atoms are assumed to be indivisible, they must unite or combine as wholes and not as parts. Although we cannot determine exactly the actual weights of the different elementary atoms. yet we can determine their relative weights by ascertaining the smallest proportions in which any two atoms that combine atom for atom will unite with each other. Such numbers will represent the relative weights of the atoms.

Atomization.—The act of obtaining liquids in a spray of finely divided particles.

Atomizer.—An apparatus for readily obtaining a finely divided jet or spray of liquid.

A jet of steam, or a blast of air, is driven across the open end of a tube that dips below the surface of the liquid to be atomized. The partial vacuum so formed draws up the liquid, which is then blown by the current into a fine spray.

Attracted Disc Electrometer.—(See *Electrometer, Attracted Disc.*)

Attraction.—Literally the act of drawing together.

In science, a name for a series of unknown causes that effect, or are assumed to effect, the drawing together of atoms, molecules or masses.

The phenomena of attraction and repulsion underlie nearly all natural phenomena. While their effects are well known, it is doubtful if anything is definitely known of their true causes.

Attraction, Atomic.——— —(See *Affinity, Chemical.*)

Attraction, Electro-Dynamic——— —The mutual

attraction of electric currents, or of conductors through which electric currents are passing. (See *Electro-Dynamics.*)

Attraction, Electro-Magnetic—— —The mutual attraction of the unlike poles of electro-magnets. (See *Electro-Magnet.*)

Attraction, Electrostatic—— —The mutual attraction exerted between unlike electric charges, or bodies possessing unlike electric charges.

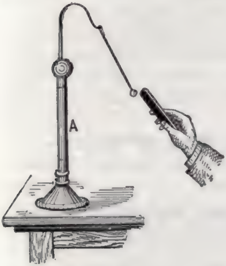


Fig. 29.

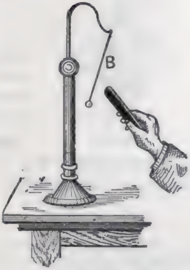


Fig. 29a.

For example, the pith ball supported on an insulated string is attracted, as shown at A, Fig. 29, by a bit of sulphur which has been briskly rubbed by a piece of silk. As soon, however, as it touches the sulphur and receives a charge, it is repelled, as shown at B, Fig. 29*a*.

These attractions and repulsions are due to the effects of *electrostatic induction.* (See *Induction, Electrostatic.*)

Attraction, Magnetic—— —The mutual attraction exerted between unlike magnet poles.

Magnetic attractions and repulsions are best shown by means of the *magnetic needle* N S, shown in Fig. 30. The N. pole of an approached magnet attracts the S. pole of the needle but repels the N. pole.

The laws of magnetic attraction and repulsion may be stated as follows, viz.:

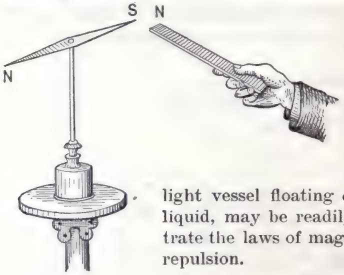


Fig. 30.

(1) Magnet poles of the same polarity repel each other.

(2) Magnet poles of unlike names attract each other.

A small bar magnet, N S, Fig. 31, laid on the top of a light vessel floating on the surface of a liquid, may be readily employed to illustrate the laws of magnetic attraction and repulsion.

Attraction, Mass or Molar—Gravitation.—The mutual attraction exerted between masses of matter. (See *Gravitation.*)

Fig. 31.

Attraction, Molecular.—The mutual attraction exerted between molecules.

The attraction of like molecules, or those of the same kind of matter, is called *Cohesion ;* that of unlike molecules, *Adhesion.*

The strength of iron or steel is due to the cohesion of its molecules. Paint adheres to wood, or ink to paper, by the attraction between unlike molecules.

Audiphone.—A thin plate of hard rubber placed in the human mouth in contact with the teeth, and maintained at a certain tension by strings attached to one of its edges, for the purpose of aiding the hearing.

The plate is so held that the sound-waves from a speaker's voice impinge directly against its flat surface. It operates by means of some of the waves being transmitted to the ear directly through the bones of the head.

Aurora Borealis.—Literally, the Northern Light. Luminous sheets, columns, arches, or pillars of a pale flashing light, generally of a red color, seen in the northern heavens.

The auroral light assumes a great variety of appearances, to which the terms *auroral arch, bands, coronæ, curtains* and *streamers* are applied.

The exact cause of the aurora is not as yet known. It would appear, however, beyond any reasonable doubt, that the auroral flashes are due to the passage of electrical currents or discharges through the upper, and therefore rarer, regions of the atmosphere. The intermittent flashes of light are probably due to the discharges being influenced by the earth's magnetism.

Auroras are frequently accompanied by *magnetic storms.* (See *Magnetic Storms.*)

The occurrence of auroras is often simultaneous with that of an unusual number of *sun spots.* Auroras are therefore probably connected with outbursts of the solar energy. (See *Sun Spots.*)

The auroral light examined by the spectroscope gives a *spectrum* characteristic of luminous gaseous matter, *i. e.*, contains a few bright lines ; but, according to S. P. Thompson, this spectrum is produced by matter that is not referable with certainty to that of any known substance on the earth.

Whatever may be the exact cause of auroras, their appearance is almost exactly reproduced by the passage of electric discharges through vacuous spaces. (See *Geissler Tubes.*)

Aurora Australis.—The Southern Light. A name given to an appearance in the southern heavens similar to that of the *Aurora Borealis,*

Austral Pole.—A name sometimes employed in France for the *north-seeking pole* of a magnet.

That pole of a magnet which points to the earth's geographical north.

It will be observed that the French regard the magnetism of the earth's Northern Hemisphere as north, and so name the *north-seeking pole* of the needle, the *austral* or *south pole.*

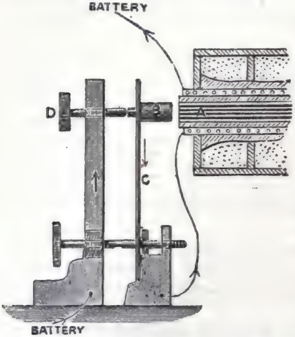


Fig. 32.

The *south-seeking* pole of the magnet is sometimes called the *boreal* or *north pole.* (See *Boreal Pole.*)

Automatic Burner.—(See *Burner, Automatic, Electric.*)

Automatic Contact Breaker, or Automatic Make-and-Break.—A device for causing an electric current to rapidly make and break its own circuit.

The spring *c*, Fig. 32, carries an armature of soft iron, B, and is placed in a circuit in such a manner that the circuit is closed when platinum contacts placed on the ends of D and B touch each other. In this case the armature B is attracted to the core A, of the electro-magnet, thus breaking the circuit and causing the magnet to lose its magnetism. The elasticity of the spring C, causes it to fly back and again close the contacts, thus again energizing the electro-magnet and again attracting B, and breaking the circuit. The makes and breaks usually follow each other so rapidly as to produce a musical note. (See *Alarm, Electric.*)

Automatic Cut-Out, Electric ——— —A device by means of which an electric circuit is either opened or short circuited, whenever the current passing might injure the *electro receptive devices.* (See *Short Circuit.*)

The safety devices for arc lights, or series circuits, differ in their construction and operation from those for incandescent lights, or multiple circuits. (See *Circuits, Varieties of. Safety Device for Arc Light Circuits. Safety Catch. Cut-out, Automatic. Safety-Fuse. Safety-Strip. Fusible Plug.*)

Automatic Regulation.—Such a regulation of a dynamo-electric machine as will preserve constant either the current or the electro-motive force generated by it.

The automatic regulation of dynamo-electric machines may be accomplished in the following ways, viz.:

(1) By a *Compound Winding* of the machine.

This method is particularly applicable to constant-potential machines. By this winding the magnetic strength of the shunt-coils is constant, while that of the series-coils varies proportionally to the load on the machine. The series-coils are preferably wound close to the poles of the machine, and the shunt-coils nearer the yoke of the magnets. Custom, however, varies in this respect, and very generally the shunt-coils are placed nearer the poles than the series-coils. (See *Compound-Winding, Dynamo-Electric Machines.*)

(2) By Shifting the Position of the Collecting Brushes.

In the Thomson-Houston system the current is kept practically constant by the following devices: The collecting brushes are fixed to levers moved by the *regulator magnet* R, as shown in Fig. 33, the armature of which is provided with an opening for the entrance of the paraboloidal pole piece A. A *dash-pot* is provided to prevent too sudden movement.

When the current is normal, the coil of the regulator magnet is short-circuited by contact points at S T which act as a shunt of very low resistance. These contact-points are operated by the solenoid coils of the *Controller* traversed by the main current. The cores of this solenoid are suspended by a spring. When the current becomes too strong the contact-point is opened, and the current, traversing the coil of the regulator magn et A attracts its armature, which shifts

the collecting brushes into a position at which a smaller current is taken off. A carbon shunt, r, of high resistance, is provided to lessen the spark at the contact-points S T, which occurs on opening the circuit.

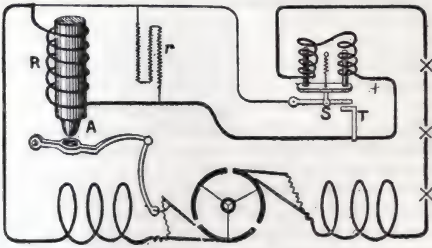


Fig. 33.

In operation the contact-points are continually opening and closing, thus maintaining a practically constant current in the external circuit.

(3) *By the Automatic Variation of a Resistance* shunting the field magnets of the machine, as in the Brush System.

In Fig. 34, the variable resistance C forms a part of the shunt circuit around the field magnets F M. This resistance is formed of a pile of carbon plates. On an increase of the current, such, for example, as would result from turning out some of the lamps, the electro-magnet B, placed in the main circuit, attracts its armature A, and, compressing the pile of carbon plates C, lowers their resistance, thus diverting a proportionally larger portion of the current from the field magnet coils F M, and maintaining the current practically constant.

In some machines the same thing is done by hand, but this is objectionable, since it requires the presence of an attendant.

4. *By the Introduction of a Variable Resistance* into the shunt circuit of the machine, as in the Edison and other systems.

This resistance may be adjusted either automatically by an electro-magnet whose coils are in an independent shunt across the mains, or may be operated by hand.

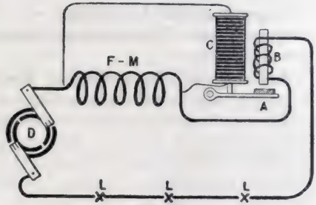


Fig. 34.

In Fig. 35, the variable resistance is shown at R, the lever switch being in this case operated by hand whenever the potential rises or falls below the proper value.

The machine shown is thus enabled to maintain a *constant potential* on the leads to which the lamps, L L L, etc., are connected in multiple-arc.

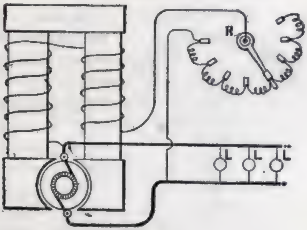


Fig. 35.

5. *Dynamometric Governing*, in which a series dynamo is made to yield a constant current by governing the steam engine that drives it, by means of a dynamometric governor that maintains a constant *torque* or turning moment, instead of the usual contrifugal governor which maintains a constant speed.

6. *Electric Governing* of the *Driving Engine*, in which the

governor is regulated by the current itself instead of by the speed of rotation as usual.

(See Addendum *Automatic Regulation.*)

Automatic Telegraphy.—(See *Telegraphy, Automatic.*)

Automatic Telephone Switch.—(See *Switch, Telephone, Automatic.*)

Average Electro-Motive Force.—The mean value of a number of separate electro-motive forces of different values.

When a wire in the armature of a dynamo-electric machine cuts the lines of magnetic force in the field of the machine, the electro-motive forces produced depend on the number of lines of force cut per second. This will vary for different positions of the coil. The mean of the varying E. M. F.'s is the average E. M. F.

Axes of Co-Ordinates.—(See *Co-Ordinates, Axes of.*)

Axis of Abscissas.—(See *Abscissas, Axis of.*)

Axis of Ordinates.—(See *Abscissas, Axis of.*)

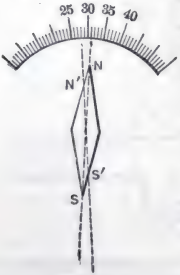


Fig. 36.

Axis, Magnetic —— of a Straight Needle.—A straight line drawn through the magnet, joining its poles.

The magnetic axis of a straight needle may be regarded as a straight line passing through the poles of the needle and its point of support.

The magnetic axis may not correspond with the geometric axis of the needle. This leads to an error in reading the true direction in which the needle is pointing, which must be corrected. Thus, the needle N S, Fig. 36, points to 31° on the scale. In reality, if the magnetic axis of the needle lies in the line N′ S′, the true deflection of the needle is only 28°.

Azimuth.—In astronomy, the angular distance between an azimuth circle and the meridian.

The azimuth of a heavenly body in the Northern Hemisphere is measured on the arc of the horizon intercepted between the north point of the horizon, and the point where the great circle that passes through the heavenly body cuts the horizon.

Azimuth Circle.—The arc of a great circle passing through the point of the heavens directly overhead, called the *Zenith*, and the point directly beneath, called the *Nadir*.

Azimuth Compass.—A compass employed by navigators for measuring the horizontal distance of the sun or a star from the magnetic meridian. (See *Compass, Azimuth.*)

Azimuth, Magnetic ——— —The arc intercepted on the horizon between the magnetic meridian and a great circle passing through the observed body.

B. A. Ohm.—The British Association Unit of Resistance, adopted prior to 1884.

The value of the Unit of Electric Resistance, or the ohm, was determined by a Committee of the British Association as being equal to the resistance of a column of mercury at 0° C., one square millimetre in area of cross-section and 104.9 centimetres in length. This length was taken as coming nearest the value of the true ohm deduced experimentally from certain theoretical considerations. Subsequent re-determinations showed the value so obtained to be erroneous. The value of the ohm is now taken internationally, as adopted by the International Electric Congress in 1884, as the resistance of a column of mercury 106 centimetres in length, and one square millimetre in area of cross-section. This last value is called the *legal ohm*, to distinguish it from the B. A. ohm which, as above stated, is equal to a mercury column 104.9 centimetres in length. Usage now sanctions the use of the word *ohm* to mean the legal ohm.

This value of the legal ohm is provisional until the exact length of the mercury column can be finally determined.

The following are the relative values of these units, viz.:

1 Legal Ohm	=	1.0112 B. A. Ohm.
" "	=	1.0600 Siemens Unit.
1 B. A. Ohm	=	.9889 Legal Ohm.
1 B. A. Ohm	=	1.0483 Siemens Unit.
1 Siemens Unit	=	.9540 B. A. Ohm.
" "	=	.9434 Legal Ohm.

Back Electro-Motive Force.—A term sometimes used for Counter Electro-Motive Force. The term counter electromotive force is the preferable term. (See *Counter Electro-Motive Force.*)

Back or Return Stroke of Lightning.—An electric shock, caused by an induced charge, produced after the discharge of a lightning flash.

The shock is not caused by the lightning flash itself, but by a charge which is induced in neighboring conductors by the discharge. A similar effect may be noticed by standing near the conductor of a powerful electric machine, when shocks are felt at every discharge.

The effects of the return shock are sometimes quite severe. They are often experienced by sensitive people on the occurrence of a lightning discharge at a considerable distance.

In some instances the return stroke has been sufficiently intense to cause death. In general, however, the effects are much less severe than those of the direct lightning discharge.

Balance, Arms of—— —(See *Arms of Bridge* or *Electric Balance.*)

Balance, Bi-filar Suspension —— —An instrument similar in its construction to Coulomb's torsion balance, but in which the needle is hung by two fibres instead of a single one.

Any deflection of the needle shortens the vertical distance between the points of support and the needle, and so tends to lift the needle. The motions are therefore balanced against the force of gravity instead of against the torsion of the fibre.

A bi-filar suspension is shown in Fig. 37. The two threads, *a b* and *a′ b′*, are connected to the needle M N, so as to permit it to hang in a true horizontal position. Any twisting around the imaginary axis *c c′*, causes the lines of suspension, *a b* and *a′ b′*, to tend to cross one another and so shorten the axis *c c′*.

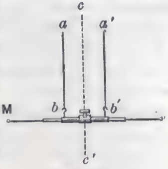


Fig. 37.

Harris, who was the first to employ the bi-filar suspension, showed that the reactive force imparted to the suspension-threads by turning the needle was :

(1) Directly proportional to the distance between the threads.

(2) Inversely as their lengths.

(3) Directly proportional to the weight of the suspended body.

(4) As the angle of twist or torsion of the threads on each other.

Balance, Coulomb's Torsion——An apparatus to measure the force of electric or magnetic repulsion between two similarly charged bodies, or between two similar magnet poles, by opposing to such force the torsion of a thin wire.

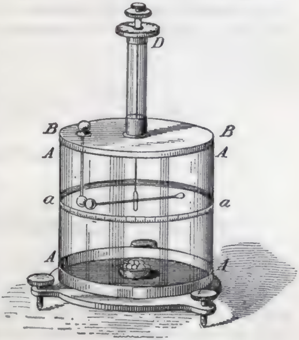


Fig. 38.

The two forces *balance* each other ; hence the origin of the term.

Fig. 38 represents a Coulomb torsion balance adapted to the measurement of the force of electrostatic repulsion. A delicate needle

of shellac, having a small gilded pith ball at one of its ends, is suspended by a fine metallic wire. A *proof-plane* B is touched to the electrified surface whose charge is to be measured, and is then placed as shown in the figure. (See *Proof-Plane.*) There is a momentary attraction of the needle, and then a repulsion, which causes the needle to be moved a certain distance from the ball on the proof-plane. This distance is measured in degrees on a graduated circle *a a* marked on the instrument. The force of the repulsion is calculated by determining the amount of torsion required to move the needle a certain distance towards the ball of the electrified proof-plane.

This torsion is obtained by the movement of the *torsion head* D, the amount of which motion is measured on a graduated circle at D. The measurement is based on the fact that the torsional force of a wire is proportional to the angle of torsion.

Balance, Hughes' Induction ———An apparatus for the detection of the presence of a metallic substance by the aid of induced electric currents.

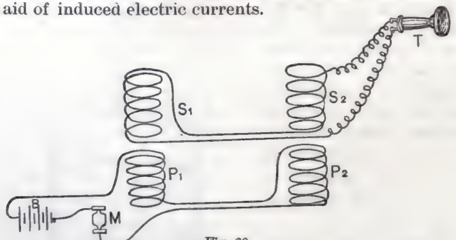


Fig. 39.

Two small *primary coils* of wire, P_1 and P_2, Fig. 39, are placed in the circuit of the battery B, and *microphone* M, (See *Microphone.*) Two small secondary coils, S_1 and S_2, are placed near them in the circuit of a telephone, T. When the induction between P_1 and S_1 is exactly equal to that between

P_2 and S_2 no sound is heard in the telephone, since the currents induced in S_1 and S_2 exactly neutralize or balance each other's effects.

If a single coin or mass of metal be introduced between either S_1 and P_1, or S_2 and P_2, the balance will be disturbed and a sound will be heard, since some of the induction is now expended in producing electric currents in the interposed metal, and a sound will therefore be heard in the telephone. But if precisely similar metals are placed in similar positions, between S_1 and P_1, and S_2 and P_2, no sound is heard in the telephone, since the inductive effects due to the two metals are the same.

The slightest difference, however, either in composition, size, or position, destroys the balance, and causes a sound to be heard in the telephone.

A spurious coin is thus readily detected when compared with a genuine coin.

A somewhat similar instrument has been employed to detect and locate a bullet or other foreign metallic substance in the human body.

Balance, Thermic—— —(See *Bolometer, or Thermic Balance.*)

Balance, Wheatstone's Electric—— —A device for measuring the value of electric *resistances.*

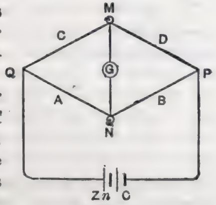


Fig. 40.

A, B, C and D, Fig. 40, are four electric resistances, any one of which can be measured in *ohms*, provided the absolute value of one of the others, and the relative values of any two of the remaining three are known in ohms.

A voltaic battery, *Zn* C, is connected at Q and P, so as to branch at P and again unite at Q, after passing through the conductor D C and B A.

A sensitive galvanometer, G, is connected at *M N*, as shown.

The passage of a current through any resistance is attended by a fall of potential that is proportional to the resistance. (See *Potential, Electric.*) If then the resistances A, C and B, are so proportioned to the value of the unknown resistance D, that no current passes through the galvanometer G, the two points, M and N, in the two circuits, Q M P and Q N P, are at the same potential. That is to say, the fall of potential along Q M P and Q N P, at the points M and N, is equal. Since the fall of potential is proportional to the resistance it follows that

$$A : B :: C : D,$$
$$\text{or } A \times D = B \times C,$$
$$\text{or } D = \left(\frac{B}{A}\right) C.$$

If then we know the values of A, B and C, the value of D can be readily calculated.

By making the value $\frac{B}{A}$ some simple ratio, the value of D is easily obtained in terms of C.

The resistances A, B and C, may consist of coils of wire whose resistance is known. To avoid their magnetism affecting the needle during the passage of the current through them, they should be made of wire bent into two parallel wires and wrapped in coils called *resistance coils*, or a *resistance-box* may be used. (See *Coils, Resistance. Box, Resistance.*)

There are two general forms of Wheatstone's Balance, viz.: the box form, and the sliding form.

Balance, Wheatstone's Electric ——, Box or Commercial Form of Wheatstone's Bridge.—A commercial form of bridge or balance in which all three known arms or branches of the bridge consist of standardized resist-

ance coils, whose values are given in ohms. (See *Coils, Resistance.*)

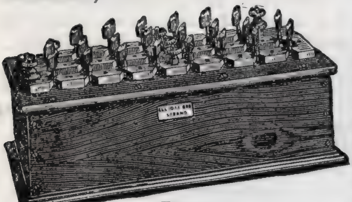


Fig. 41.

The box form of bridge is shown in perspective in Fig. 41, and in plan in Fig. 42. The bridge arms, corresponding to the resistances A and B, of Fig. 40, consist of resistance coils of 10, 100, and 1,000 ohms each, inserted in the arms $q\,z$, and $q\ x$, of Fig. 42. (See *Balance, Wheatstone's Electric.*) These are called the *proportional coils.* The arm corresponding to resist-

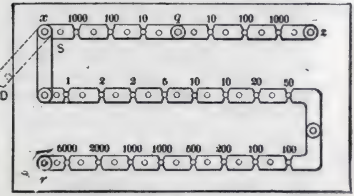


Fig. 42.

ance C, of Fig. 40, is composed of separate resistances of 1, 2, 2, 5, 10, 10, 20, 50, 100, 100, 200 500, 1,000, 1,000, 2,000, and 5,000 ohms. In some forms of box bridges, additional decimal resistances are added.

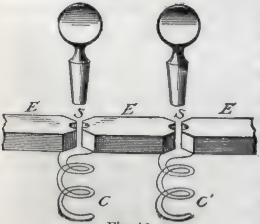


Fig. 43.

The resistance coils are wound, as shown in Fig. 43, after the wire has been bent on itself in the middle, in order to avoid the effects of induction, among which are a disturbing action on a galvano-

meter used near them, and the introduction of a spurious resistance in the coils themselves. (See *Spurious Resistance.*)

To avoid the effects of changes of resistance occasioned by changes of temperature, the coils are made of German silver, or preferably of alloys called *Platinoid*, or *Platinum silver.* (See *Platinoid. Platinum Silver.*) Even when these alloys are used, care should be taken not to allow the currents used to pass through the resistance coils but for a few moments.

The coils, C C′, are connected with one another in series by connecting their ends to the short, thick pieces of brass, E E E, Fig. 43. On the insertion of the plug keys, at S S, the coils are cut out by short-circuiting. Care should be taken to see that the plug keys are firmly inserted and free from grease or dirt, otherwise the coil will not be completely cut out.

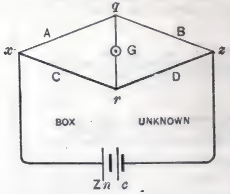


Fig. 44.

The following are the connections, viz.: The galvanometer is inserted between q and r, Fig. 44; the unknown resistance between z and r; the battery is connected to x and z. A convenient proportion being taken for the value of the proportional coils, resistances are inserted in C, until no deflection is shown by the galvanometer G. The similarity between these connections and those shown in Fig. 42. will be seen from an inspection of Fig. 44. (See *Balance, Wheatstone's Electric.*) The arms, A and B, correspond to $q\ x$ and $q\ z$, of Fig. 42; C, to the arm $x\ r$, Fig. 42; and D, to the unknown resistance. We then have as before

$$A : B : : C : D., \text{ or } A \times D = B \times C, \therefore D = \left(\frac{B}{A}\right) C.$$

The advantage of the simplicity of the ratios, A and B, or 10, 100, and 1,000, of the Bridge Box, will therefore be mani-

fest. The battery terminals may also be connected to q and r, and the galvanometer terminals to x and z, without disturbing the proportions.

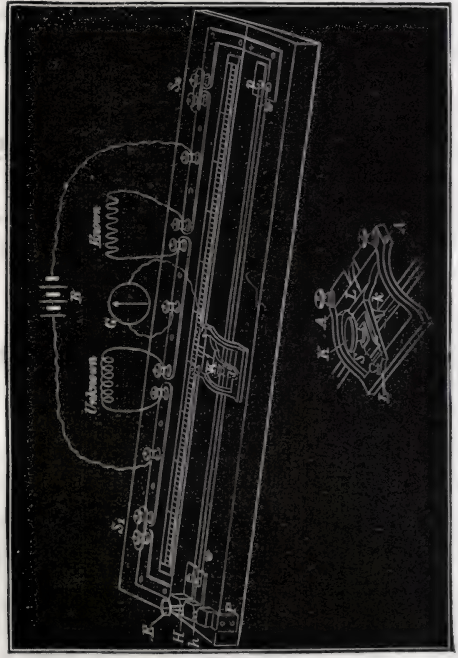


Fig. 45.

Balance, Wheatstone's, Slide Form of—— —A

balance in which the proportionate arms of the bridge are formed of a single thin wire, of uniform diameter, generally of German silver, of comparatively high resistance.

A *Spring Key* slides over the wire; one terminal of the key is connected with the galvanometer and the other with the

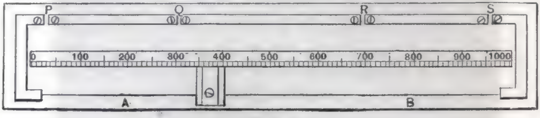


Fig. 46.

wire when the spring key is depressed. As the wire is of uniform diameter, the resistances of the arms, A and B, Fig. 46, will then be directly proportional to the lengths. A scale placed near the wire serves to measure these lengths. A thick metal strip connected to the slide wire has four gaps at P, Q, R and S.

When in ordinary use, the gaps at P and S are either connected by stout strips of conducting material or by known resistances, in which case they act simply as ungraduated extensions of the slide wire, and, like lengthening the slide wire, increase the sensibility of the instrument.

The unknown resistance is then inserted in the gap at Q, and a known resistance, generally the *resistance box*, in that at R. The galvanometer has one of its terminals connected to the metal strip between Q and R, and its other terminal to the sliding key. The battery terminals are connected to the metal strips between P and Q, and R and S, respectively.

These connections are more clearly seen in the form of bridge shown in Fig. 45. The slide wire *w w*, consists of three separate wires each a metre in length, so arranged that only one wire, or two in series, or all three in series, can be used. Matters being now arranged as shown, the sliding key is moved until no current passes through the galvanometer.

The sliding bridge is not entirely satisfactory, since the uncertainty of the spring-contact causes a lack of correspondence between the point of contact and the point of the scale on which the index rests.

The loss of uniformity of the wire, due to constant use, causes a lack of correspondence between the resistance of the wire and its length. With care, however, very accurate results can be obtained.

Ballistic Curve.—The curve actually described by a projectile thrown in any other than a vertical direction through the air.

Theoretically, the path of a projectile in a vacuum is a parabola—that is, the path A E B, Fig. 47. Actually, the effects of fluid resistances cause it to take the path A C D, called a *ballistic curve*. The ballistic curve has a smaller vertical height than the parabola. The projectile also has a smaller vertical range. Instead of reaching the point B, it continually approaches the perpendicular E F.

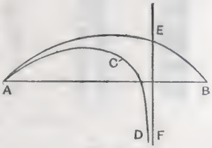


Fig. 47.

Ballistic Galvanometer.—A form of galvanometer suitable for measuring momentary currents, such as those produced by the discharge of a *condenser*, which rise rapidly from zero to a maximum, and then as rapidly fall to zero. (See *Galvanometer, Ballistic.*)

Barad.—A unit of pressure recently proposed by the British Association.

One barad equals one dyne per square centimetre.

Barometer.—An apparatus for measuring the pressure of the atmosphere.

Barometric Column.—A column, usually of mercury, approximately thirty inches in vertical height, sustained in a barometer or other tube by the pressure of the atmosphere.

The space above the barometric column contains a vacuum known as the *Torricellian vacuum.*

Bars, Krizik's ——— —Cores of various shapes, provided for solenoids, in which the distribution of the metal in the bar is so proportioned as to obtain as nearly as possible a uniform attraction or pull while in different positions in the solenoid.

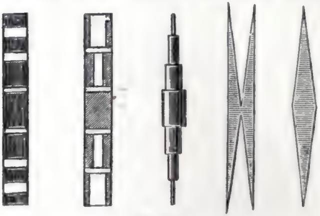


Fig. 48.

Various Krizik's bars are shown in Fig. 48. As will be observed, in all cases the mass of metal is greater towards the middle of the bar or core than near the ends.

When a core of uniform diameter is drawn into a solenoid, the attraction or pull is not uniform in strength for different positions of the bar. When the bar is just entering the solenoid, the pull is the strongest; as soon as the end passes the middle of the core the attraction grows less, until, when the centres of the bar and core coincide, the motion ceases, since both ends of the solenoid attract equally in opposite directions. By proportioning the bars, as shown in the figure, a fairly uniform pull for a considerable length may be obtained.

Bath, Electro-Therapeutic ——— —A bath furnished with suitable electrodes and used in the application of electricity to curative purposes. Such baths should be used only under the advice of an intelligent physician.

Bath, Electro-Plating ——— —Tanks containing metallic solutions in which articles are placed that are to be electro-plated. (See *Electro-Plating.*)

Bathometer.—An instrument invented by Siemens for

obtaining deep-sea soundings without the use of a sounding line.

The bathometer depends for its operation on the decreased attraction of the earth for a suspended weight, that takes place in parts of the ocean differing in depth. As the vessel passes over deep portions of the ocean, the solid land of the bottom, being further from the ship, exerts a smaller attraction than it would in shallow parts, where it is nearer; for, although in the deep parts of the ocean the water lies between the ship and the bottom, the smaller density of the water as compared with the land causes it to exert a smaller attraction than in the shallower parts, where the bottom is nearer the ship. The varying attraction is caused to act on a mercury column, the reading of which is effected by means of an electric contact.

Baths, Copper, Gold, Silver, Nickel, etc.,—— —Tanks containing solutions of metals suitable for electric deposition by the process of electro-plating. (See *Electro-Plating.*)

Batteries, Varieties of Voltaic —— —(See *Cell, Voltaic, Varieties of.*)

Battery, Dynamo —— —The combination or coupling together of several separate dynamo-electric machines so as to act as a single electric source.

The dynamos may be connected to the leads either in series, in multiple-arc, in multiple-series, or in series-multiple.

Battery, Electric—— —A general term applied to the combination, as a single source, of a number of separate electric sources.

The separate sources may be coupled either in *series*, in *multiple-arc*, in *multiple-series*, or in *series-multiple*. (See *Circuits, Varieties of.*)

The term battery is sometimes incorrectly applied to a single voltaic couple or cell.

Battery, Leyden Jar—— —The combination of a number of separate Leyden jars so as to act as one single jar.

A Leyden battery is shown in Fig. 49, where nine separate Leyden jars are connected as a single jar by joining their outer coatings by placing them in the box P, the bottom of

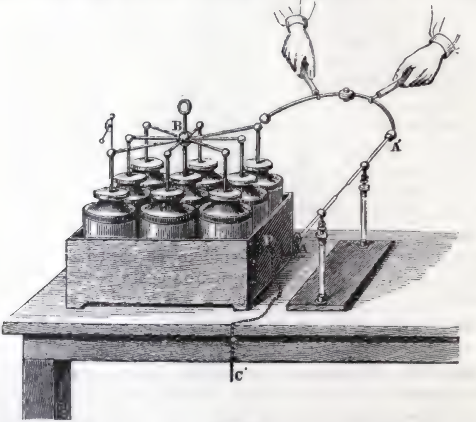


Fig. 49.

which is lined with tin foil. The inner coatings are connected together by the metal rods B, as shown.

A *discharging* rod A′ may be employed for connecting the opposite coatings. The handles are made of glass or any good insulating material.

Battery, Local—— —A voltaic battery used at either end of a telegraph line to operate the Morse sounder, or the registering or recording apparatus, at that end only. (See *Telegraphy, Morse System of.*)

The local battery is thrown into or out of action by the telegraphic *relay*. (See *Relay.*)

Battery, Magnetic —— —The combination, as a single magnet, of a number of separate magnets.

A magnetic battery, or compound magnet, is shown in Fig. 50. It consists of straight bars of steel, *p p p*, with their similar poles placed near together, and inserted in masses of soft iron, N and S, as shown.

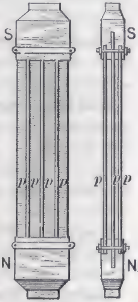


Fig. 50.

Battery, Plunge —— —A number of voltaic cells connected so as to form a single cell or electric source, the plates of which are so supported on a horizontal bar as to be capable of being simultaneously placed in, or removed from, the liquid.

The plunge battery shown in Fig. 51 consists of a number of zinc-carbon elements immersed in an electrolyte of dilute sulphuric acid, or in *electropoion liquid*, contained in separate jars, J, J. (See *Electropoion Liquid.*)

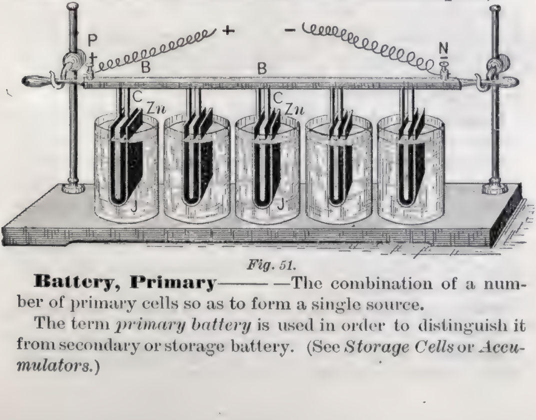


Fig. 51.

Battery, Primary —— —The combination of a number of primary cells so as to form a single source.

The term *primary battery* is used in order to distinguish it from secondary or storage battery. (See *Storage Cells* or *Accumulators.*)

Battery, Secondary ——— —The combination of a number of secondary or storage cells so as to form a single electric source. (See *Storage of Electricity.*)

Battery, Selenium ——— —The combination of selenium with another element to form an electric source when acted on by light.

Battery, Split ——— —A voltaic battery connected in series, and having one of its middle plates connected with the ground.

By this means the poles of a battery are maintained at potentials differing in opposite directions from the potential of the earth.

Battery, Thermo-Electric ——— —The combination, as a single thermo-electric cell, of a number of separate thermo-electric cells or couples. (See *Thermo-Electric Couple.*)

Battery, Voltaic, Closed-Circuit ——— —A voltaic battery which may be kept constantly on closed circuit.

The gravity battery is a closed-circuit battery. As employed for use on most telegraph lines, it is maintained on a closed circuit. When an operator wishes to use the line he opens his switch, thus breaking the circuit and calling his correspondent. Such batteries should not polarize. (See *Polarization of Voltaic Cell.*)

Battery, Voltaic, Open-Circuit ——— —A voltaic battery which is normally on open-circuit, and which is used for comparatively small durations of time on closed circuit.

The Leclanché-cell is an excellent open-circuited battery. It has a comparatively high electro-motive force, but rapidly polarizes. It cannot therefore be economically used for furnishing currents continuously for long durations of time. When left on open circuit, however, it depolarizes. (See *Cell, Voltaic, Leclanché.*)

Battery, Voltaic ——— —The combination, as a single source, of a number of separate voltaic cells.

Battery, Water ——— —A battery formed of zinc and copper couples immersed in ordinary water.

Any voltaic couple can be used, the positive element of which is capable of being slightly acted on by water. When numerous couples are employed considerable difference of potential can be obtained.

Water batteries are employed for charging electrometers. They are not capable of giving any considerable current, owing to their great internal resistance.

B. A. U.—A contraction sometimes employed for the British Association Unit or Ohm.

Bell Call, Electric ——— —An electric bell used to call the attention of an operator to the fact that his correspondent wishes to communicate with him.

Bell, Extension Call ——— —A device for prolonging the sound of a magneto call, and for sounding the signal at some distant point.

An alarm-bell is connected with the circuit of a local battery by the current generated by the magneto call, and continues sounding after the current of the magneto call has ceased.

Bell, Indicating ——— —An electric bell in which, in order to distinguish between a number of bells in the same office, a number is displayed by each bell when it rings.

Bell Magnet—(See *Magnet, Bell.*)

Bell, Magneto Call ——— Telephone Call ——— — A call-bell operated by currents generated by the rotation of an armature in a magnetic field.

Bells, Relay——— —Bells used in the early forms of of acoustic telegraphs as employed in England with relay sounders.

The dots and dashes of the Morse alphabet were indicated by the sounds of a bell, a tap on one bell indicating a dot, and a tap on the other a dash. This system is now practically abandoned.

Bias of Relay Tongue.—A term to signify the adjust-

ment of a polarized relay such that, on the cessation of the working current, the relay tongue shall always rest against the insulated contact and not against the other contact, or vice versa.

Sometimes, as in the split-battery-duplex, the bias is toward the uninsulated contact. (See *Relay, Polarized.*)

Bichromate Voltaic Cell.—(See *Cell, Voltaic.*)

Bi-Filar Balance.—(See *Balance, Bi-filar Suspension.*)

Bi-Filar Suspension.—The suspension of a needle or magnet by two fibres in place of a single fibre. (See *Balance, Bi-Filar Suspension.*)

Bi-Filar Winding of Coils.—A winding of a coil of wire such that, instead of winding it in one continuous length, the wire is doubled in itself and then wound.

This method is employed in resistance coils, so as to avoid disturbing effects on neighboring instruments. (See *Coils, Resistance.*)

Binary Compound.—In chemistry, a compound formed by the union of two different elements.

Water is a binary compound, being formed by the union of two atoms of hydrogen with one atom of oxygen. Its chemical composition is thus expressed in *chemical symbols*, viz., H_2O, which indicates two atoms of hydrogen combined, or chemically united, with one atom of oxygen.

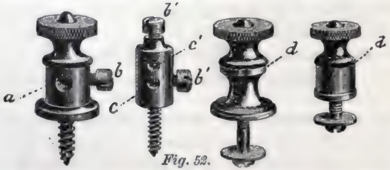


Fig. 52.

Binding Posts, or Binding Screws.—Devices for connecting the terminals of an electric source with those of an

electro-receptive device, or for connecting different parts of an electric apparatus with one another.

The conducting or circuit wire is either introduced in the opening *a*, Fig. 52, and clamped by the screw *b*; or is placed in the space, *d d*, and kept in place by means of a thumb-screw. Sometimes two openings are provided at *c* and *c′*, for the purpose of connecting two wires together.

Biology, Electro—— —(See *Electro-Biology.*)

Black Lead.—A variety of carbon employed in various electrical processes.

Black lead is also termed *plumbago* or *graphite.* (See *Plumbago. Graphite.*)

Blasting, Electric—— —The electric ignition of powder or other material in a blast. (See *Fuse, Electric.*)

Bleaching, Electric—— —Bleaching processes in which the bleaching agents are liberated as required by the agency of *electrolytic decomposition.*

In the process of Naudin and Bidet, the current from a dynamo-electric machine, is passed through a solution of common salt between two closely approached electrodes. The chlorine and sodium thus liberated react on each other and form sodium hyphochloride, which is drawn off by means of a pump and used for bleaching. (See *Electrolysis.*)

Block, Branch—— —(See *Branch Block.*)

Block System for Railways.—A system for securing safety from collisions of moving railroad trains by dividing the road into a number of blocks or sections of a given length, and so maintaining telegraphic communication between towers located at the ends of each of such blocks, as to prevent, by the display of suitable signals, more than one train or engine from being on the same block at the same time.

There are two kinds of block railway systems, viz.:

(1) The *Absolute Block System.*

(2) The *Permissive Block System.*

In the absolute system, which is of course the safest, one train only is permitted to be on any particular block at a given time.

In the permissive block system more than one train is permitted, under certain circumstance and conditions, to occupy the same block simultaneously, each train then being notified of the fact that it is not alone on the block.

The absolute block system, though expensive to construct and maintain, is the only one that should be permitted in law to exist on roads whose traffic reaches a certain amount.

The absolute block system is employed on the London Underground Railroad, and on the Pennsylvania Railroad Systems.

The system. as in use on the New York division of the Pennsylvania Railroad, is as follows :

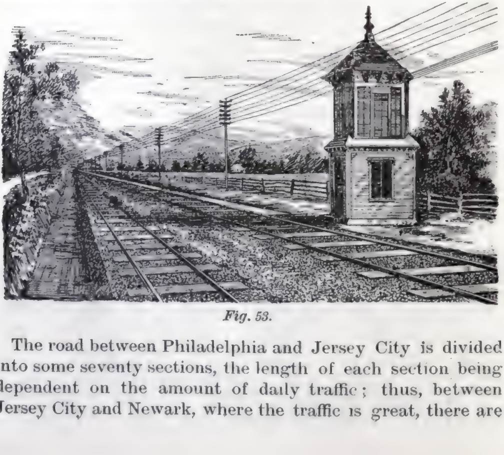


Fig. 53.

The road between Philadelphia and Jersey City is divided into some seventy sections, the length of each section being dependent on the amount of daily traffic ; thus, between Jersey City and Newark, where the traffic is great, there are

some fifteen sections, although the distance is only 7.9 miles.

In each block-tower there are connections with three separate and distinct telegraph lines or circuits, viz. :

(1) A line or wire called the *train wire*, connecting the block-tower with the General Dispatcher's office at Jersey City. This line is used for sending train orders only.

(2) A line or wire called the *block wire*, connecting each block-tower with the next tower on each side of it.

(3) A line or wire called the *message wire*, and used for local traffic or business.

The general arrangement of the block-tower is shown in Fig. 53.

Each of the block-towers is sufficiently elevated above the road-bed to afford the operator an unobstructed view of the tracks.

The operator, having ascertained the actual condition of the track either by observation, or by telegraphic communication with the stations on either side of him, gives notice of this condition to all trains passing his station by the display of certain semaphore signals.

The semaphore signals as used on this road are shown on following pages, in Figs. 54 and 55. The form shown in Fig. 54 is used in the absolute system, and that shown in Fig. 55 in the permissive system. These signals consist essentially of an upright support provided with a movable arm A B, called the *semaphore arm*, capable of being set in any of two, or three positions. The semaphore signal is placed outside the signal tower, often several hundred feet away, but is readily set from the tower in any of the desired positions by the operator, by the movement of rods connected with levers.

The semaphore arm can, in the permissive system, be set in three positions, viz.:

(1) In a horizontal position, or where the semaphore arm makes an angle of 90° with the upright.

(2) Or it may be dropped down from the horizontal position through an angle of 75°, as shown in Fig. 54.

(3) Or it may occupy a position exactly intermediate be-

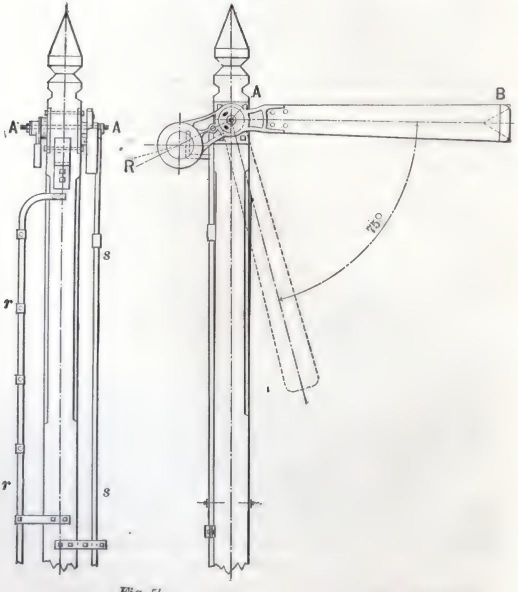


Fig. 54.

tween the first and the second, or 37° 30′ below the horizontal, as shown in Fig. 55.

Position No. 1, is the danger signal, and when it is displayed the train may not enter the block it governs.

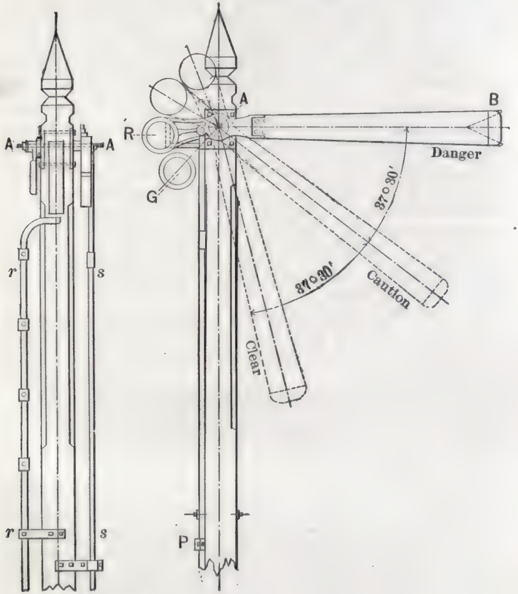


Fig. 55.

Position No. 2 shows that the track is clear, and that the train may safely enter the block it governs.

Position No. 3, which is used in the permissive block system

only signifies caution, and permits the train to cautiously enter the block and look out for further signals.

The semaphore arm consists of a light wooden arm, 11 inches wide by 5½ feet in length, painted red, or other suitable color that can be easily distinguished by daylight.

By night the positions of the semaphore arm are indicated by colored lights. These lights are operated as follows; viz., in the absolute system, the semaphore arm A B, pivoted at A, bears at its shorter end a disc or lens of red glass R, and, in the permissive system, below this another disc or lens of green glass G. An oil lantern, provided with an uncolored glass lens, is so supported on a bracket fastened to the upright that when the semaphore arm points to danger, the red glass is immediately in front of the lantern; when it points to caution, the green glass is in front of the lantern; but when it points to safety, the lantern is left uncovered save by its uncolored glass.

At night, therefore, when the semaphore arm is set to danger, a red light is displayed; when it points to caution, a green light is displayed; and when it points to safely, a white light is displayed.

The green light is only used in the permissive block system. In the absolute block system, the semaphore arm has two positions only; viz., danger, or horizontal, and safety, or 75° below the horizontal.

A single arm is used when it is intended to govern a single track only. Where the condition of a number of tracks is to be indicated, several arms are employed, one above the other.

When semaphore signals are placed on each side of a double-track road, the semaphore arm pointing to the right of the vertical support governs the line running to the right.

When the semaphore signals are placed at junctions or switch-crossings, the operator in the signal-tower opens or closes the switches from the tower by the movements of levers that set the switches, and then displays the proper

semaphore signal for that crossing or route, red, or danger, if the route is blocked, and white, or safety, if it is clear. Here the interlocking apparatus is employed, which consists in a device by means of which, when a route has once been set up and a signal given for that route, the switches and signals are so interlocked that no signal can possibly be given for a conflicting route.

The signals or switches are operated by means of iron rods passing over rollers or pulleys. These rods are attached by suitable connections to the switch or semaphore signals, and are operated by means of levers from the signal-tower. Switches can be operated as far as 1,000 feet from the tower; signals as far as 2,500 feet.

Colored switch-signals are placed opposite the end of the switches to indicate the positions of the switch. These signals consist of red and white discs for day, and a lantern provided with red and white glasses for night. When the switch on any line is open, the switch-signal shows red; when shut, it shows white. These switch-signals are only used in the yards.

No passenger train is permitted on a block, after another train has passed the signal station, until a dispatch has been received from the station ahead that the train has passed and the block is thus cleared.

As an additional precaution against rear collisions, *tail-lights* are displayed at the ends of the trains. These consist of lanterns placed on each side of the rear end of the last car. These lanterns are furnished with three glass slides. The side of the lantern towards the rear of the car shows a *red* light; that to the front and side of the car shows a green light. The engineer, looking out of the cab, can thus see a green light, which serves as a "*marker*" and indicates to him that his train is intact. By day a green flag, placed in the same position as the lantern, serves the same purpose as a *marker*. An observer on the track, or in the tower, sees the red lights on the rear of the train when it has passed.

Freight trains are now run on separate tracks, except in places where the extra tracks are not yet completed. Here they do not run on schedule time, but are permitted to follow one another at intervals that depend on the condition of the tracks as shown by the signals displayed.

Blow-Pipe, Electric ——— —A blow-pipe in which the air-blast is supplied by the stream of air particles produced at the point of a charged conductor by the convection discharge.

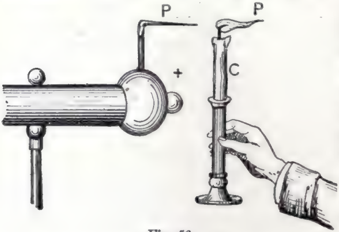


Fig. 56.

The candle flame Fig. 56, is blown in the direction shown by the stream of air particles passing off from the point P. (See *Convection, Electric.*)

Blow-Pipe, Electric Arc ——— —A device of Werdermann for cutting rocks, or other refractory substances, in which the heat of the voltaic arc is directed by means of a magnet, or blast of air, against the substance to be cut.

The carbons are placed parallel, so as to readily enter the cavity thus cut or fused. This invention has never been introduced into extensive practice.


Fig. 57.

As shown in Fig. 57 the voltaic arc, taken between two vertical carbon electrodes, is deflected into a horizontal position under the influence of the inclined poles of a powerful electro-magnet.

The highly heated carbon vapor that constitutes the voltaic arc is deflected by the magnet in

the same direction as would be any other movable circuit or current.

Board, Multiple Switch ——— —A board to which the numerous circuits employed in systems of telegraphy, telephony, annunciator, or electric light and power circuits, are connected.

Various devices are employed for closing these circuits, or for connecting, or cross-connecting, them with one another, or with neighboring circuits.

A multiple switch board, for example, for a telephone exchange, will enable the operator to connect any subscriber on the line with any other subscriber on that line, or on another neighboring line provided with a multiple switchboard. To this end the following parts are necessary:

(1) Devices whereby each line entering the exchange can readily have inserted in its circuit a loop connecting it with another line. This is accomplished by placing on the switchboard a separate *spring-jack* connection for each separate line. This connection consists essentially of one or two springs made of any conducting metal, which are kept in metallic contact but which can be separated from one another by the introduction of the *plug key*, Fig. 58, the terminals, *a* and *b*, of which are insulated from each other, and are connected to the ends of a loop coming from another line. As the key is inserted, the metallic spring or springs of the spring-jack are separated, and the metallic pieces, *a* and *b*, brought into good sliding contact therewith, thus introducing the loop into the circuit. (See *Spring-Jack.*)

Fig. 58.

(2) As many separate Annunciator Drops as there are separate subscribers. These are provided so as to notify the Central Office of the particular subscriber who desires a connection. Alarm-bells, to call the operator's attention to the calling

subscriber, or to the falling of a drop, are generally added. (See *Annunciators. Bell Call, Electric.*)

(3) Connecting Cords and Keys for connectiong the operator's telephone, and means for ringing subscribers' bells, and clearing out drops.

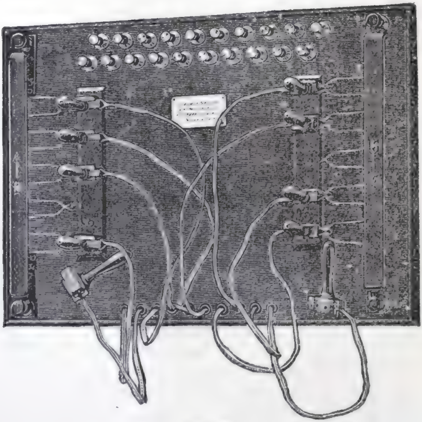


Fig. 59.

In *Electric Light Switch-Boards,* or *Distributing Switches,* spring-jack contacts are connected with the terminals of different circuits, and plug-switches with the dynamo terminals. By these means, any dynamo can be connected with any circuit, or a number of circuits can be connected with the same dynamo, or a number of separate dynamos can be placed in the same circuit, without interference with the lights.

Boat, Electric——— —A boat provided with electric motive power.

Electric power has been applied both for ordinary vessels and for sub-marine torpedo boats.

Bobbins, Electric——— —An insulated coil of wire for an electro-magnet. (See *Coils, Electric.*)

Body Protector, Electric——— —A device for protecting the human body against the accidental passage of an electric discharge.

To protect the human body from the accidental passage through it of dangerous electric currents, Delany places a light, flexible, conducting wire, A A B L L, in the position shown in Fig, 60, for the purpose of leading the greater part of the current around instead of through the body.

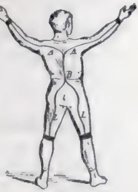


Fig. 60.

Inside insulating shoe-soles for lessening the danger from accidental contacts through grounded circuits have also been proposed.

Boiler-Feed, Electric——— —A device for automatically opening a boiler-feed apparatus electrically, when the water in the boiler falls to a certain predetermined point.

Bole.—A unit recently proposed by the British Association.

One bole is equal to one gramme-kine.

Bolometer, or Langley's Thermic Balance.—An apparatus for determining small differences of temperature, constructed on the principle of the *differential galvanometer.* (See *Galvanometer, Differential.*)

A coil composed of two separate insulated wires, wound together, is suspended in a magnetic field, and has a current sent through it. Under normal conditions, this current separates into two equal parts, and runs through the wires in opposite

directions. It therefore produces no sensible field, and suffers no deflection by the field in which it is suspended.

Any local application of heat, however, causing a difference in resistance, prevents this equality. A field is therefore produced in the suspended coil, which, though extremely small, is rendered measurable by means of the powerful field produced in the coil, within which the double coil is suspended.

Differences of temperature as small as $\frac{1}{14000}$ degree F. are detected by the instrument.

Bombardment, Molecular————The forcible rectilinear projection of molecules in exhausted vessels, that takes place from the negative electrode, on the passage of electric discharges. (See *Matter, Radiant.*)

Boreal Magnet Pole.—A name sometimes employed in France for the south-seeking pole of a magnet, as distinguished from the austral, or north-seeking pole.

That pole of a magnet which points toward the geographical south.

If the earth's magnetic pole in the Northern Hemisphere be of north magnetism, then the pole of a needle that points to it must be of the opposite polarity, or of south magnetism. In this country we call the end which points to the north the *north-seeking end,* or the *marked pole.* In France, the end which points to the north is called the *austral pole.* Austral means south pole. (See *Austral Magnet Pole.*)

The austral is therefore the north-seeking pole, and the boreal, the south-seeking pole.

Boucherizing.—A process adopted for the preservation of wooden telegraph poles, by injecting a solution of copper sulphate into the pores of the wood. (See *Poles, Telegraphic.*)

Bound and Free Charge.—The condition of an electric charge on a conductor placed near another conductor,

but separated from it by a medium through which *electrostatic induction* can take place. (See *Induction, Electrostatic.*)

The charge, on a completely isolated conductor, readily leaves it when put in contact with a good conductor connected with the ground. The charge in this condition is called a *free charge.* When, however, the conductor is placed near another conductor, but separated from it by a medium through which induction can take place, a charge of the opposite name is induced in the neighboring conductor. This charge is held or bound on the conductor by the mutual attraction of the opposite charges.

To discharge a bound charge, both conductors must be simultaneously touched by any good conducting substance. The bound charge was formerly called *dissimulated* or *latent electricity.* (See *Charge. Dissimulated* or *Latent Electricity.*)

Box Bridge.—(See *Balance, Wheatstone's Electric, Box Form of.*)

Box, Distribution——for Electric Arc Light Circuits.—A device by means of which arc and incandescent lights may be simultaneously employed on the same line, from a constant current dynamo electric-machine or other source.

A portion of the line circuit, whose difference of potential is sufficient to operate the electro-receptive device, as for example an incandescent lamp, is divided into such a number of multiple circuits as will provide a current of the requisite

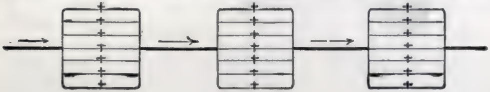


Fig. 61.

strength for each of the devices. In order to protect the remaining of these devises so interpolated, on the extinguishment of any of the devices, automatic cut-outs are provided

which divert the current thus cut off through a resistance equivalent to that of the device.

A variety of distribution boxes are in use.

The character of circuit employed in connection with distribution boxes is shown in Fig. 61. (See *Circuits, Varieties of.*)

Box, Resistance——— —A box containing a number of standardized resistance coils.

The resistance box and coils are of the same general construction as the Box Bridge. (See *Balance, Wheatstone's Electric, Box Form of.*)

Bracket, Lamp——— —A device for holding or supporting an electric lamp, similar to a bracket for a gas burner.

Fig. 62.

Fig. 63.

Fig. 64.

Lamp brackets are either fixed or movable. Those shown in Figs. 62 and 63 are fixed. That shown in Fig. 64 is movable.

Brackets, Telegraphic ——— or Arms.—The supports or cross pieces on telegraph poles, provided for the insulators of telegraphic lines.

Telegraphic insulators are supported either on wooden *arms*, or on iron or metal *brackets*.

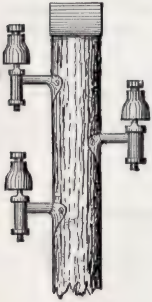


Fig. 65.

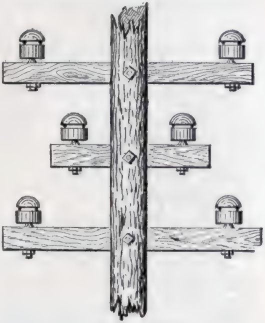


Fig. 66.

Fig. 65, shows a form of iron bracket. Fig. 66, shows a form of wooden arm.

Various well known modifications of these shapes are in common use. For details see *Telegraph Poles.*

Brake, Electro-Magnetic—— —A brake for car wheels, the braking powers for which is either derived from electro-magnetism, or is thrown into action by electro-magnetic devices.

Electro-magnetic car brakes are of a great variety of forms. They may, however, be arranged in two classes, viz.:

(1) Those in which magnetic adhesion or the magnetic attraction of the wheels to the brake is employed.

(2) Ordinary brake mechanism in which the force operating the brake is thrown into action by an electro-magnet.

Brake, Prony or Friction—— —A mechanical device for measuring the power of a driving shaft.

An inflexible beam, Fig. 67, is provided at one end with a clamping device for clamping the driving shaft, and at the other end A, with a pan for holding weights.

Fig. 67.

If the brake be arranged as shown in Fig. 67, and the shaft rotate in the direction of the arrow, the tendency is to carry the beam around with it, placing it at one moment in the position shown by the dotted line. If a sufficiently heavy weight be placed at x, in a pan hung at A, the beam will assume a vertical position downwards. If, however, the *torque*, or twisting force of the driving shaft be balanced by the weight, the bar will remain horizontal. The power can then be calculated by multiplying the weight in pounds by the circumference in feet of the circle of which the bar is a radius, and this product by the number of turns of the driving shaft per minute. The product will be the number of foot-pounds per minute, and, when divided by 33,000, will give the *Horse-Power*. (See *Horse-Power*.)

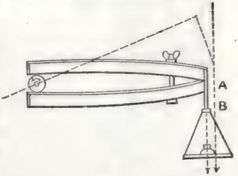


Fig. 68.

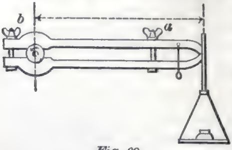


Fig. 69.

Some modified forms of the Prony Brake are shown in Figs. 68, and 69.

Branch-Block.—A device employed in electric wiring for taking off a branch from a main circuit.

Breaking Weight of Telegraph Wires.—The weight which when hung at the end of a wire will break it.

Ordinary copper wire will break at about 17 tons to the square inch of cross-section. Common wrought iron breaks at 25 tons to the square inch. When drawn, the breaking weight is often as great as 40 or 50 tons to the square inch. These figures are to be regarded as approximate only, since differences in the physical conditions of metals, as well as slight variations in their chemical composition, often produce marked differences in their breaking weights.

Breath Figures, Electric—— —(See *Figures, Electric or Breath.*)

Bridge, Electric—— —(See *Balance, Wheatstone's Electric.*)

Bridge, Magnetic —— —An apparatus invented by Edison for measuring magnetic resistance, similar in principle to Wheatstone's Electric Bridge.

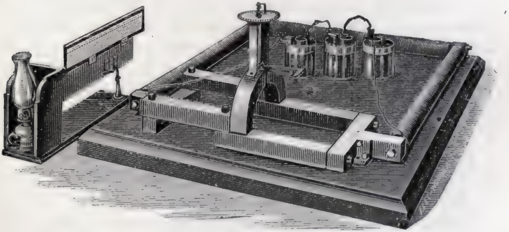


Fig. 70.

The magnetic bridge is based on the fact that two points at the same magnetic potential fail, when connected, to produce any action on a magnetic needle. The magnetic bridge may be arranged as shown in Fig. 70, of four sides made of pure, soft iron. The poles of an electro-magnet are connected, as shown, to projections at the middle of the short side of the rectangle. By this means a difference of magnetic potential is

maintained at these points. The two long sides are formed of two halves each, which form the four arms of the balance. Two of these only are movable.

Two curved bars of soft iron, of the same area of cross-section as the arms of the bridge, rest on the middle of the long arms, in the arched shape shown. Their ends approach near the top of the arch within about a half inch. A space is hollowed out between these ends, for the reception of a short needle of well-magnetized hardened steel, suspended by a wire from a torsion head.

The movements of the needle are measured on a scale by a spot of light reflected from a mirror.

The electro-magnet maintains a constant difference of magnetic potential at the two shorter ends of the rectangle. If, therefore, the four bars, or arms of the bridge, are magnetically identical, there will be no deflection, since no difference of potential will exist at the ends of the bars between which the needle is suspended. If one of the bars or arms, however, be moved even a trifle, the needle is at once deflected, the motion becoming a maximum when the bar is entirely removed. If replaced by another bar, differing in cross-section, constitution, or molecular structure, the balance is likewise disturbed.

The magnetic bridge is very sensitive. It was designed by its inventor for testing the magnetic qualities of the iron used in the construction of dynamo-electric machines.

Bridge, Wheatstone's Electric ——— —(See *Wheatstone's Balance, Electric.*)

Broken Circuit.—An open circuit.

A circuit, the electrical continuity of which has been broken, and through which the current has therefore ceased to pass.

Broken Circuit.—(See *Circuit, Broken.*)

Brush Discharge ——— — The faintly luminous discharge that occurs from a pointed positive conductor. (See *Discharge, Convective.*)

Brush, Faradic————An electrode in the form of a brush employed in the medical application of electricity.

The bristles are generally made of nickelized copper wire.

Brush Holders for Dynamo-Electric Machines.—Devices for supporting the collecting brushes of dynamo-electric machines.

As the brushes require to be set or placed on the commutator in a position which often varies with the speed of the machine, and with changes in the external circuit, all brush holders are provided with some device for moving them concentrically with the commutator cylinder.

Brushes, Adjustment of the——of Dynamo-Electric Machines.—Shifting the brushes into the required position on the commutator cylinder, either non-automatically by hand, or *automatically* by the current itself. (See *Automatic Regulation of Dynamo-Electric Machines.*)

Brushes for Dynamo-Electric Machines.—Strips of metal, bundles of wire, or slit plates of metal, or carbon, that bear on the commutator cylinder and carry off the current generated.

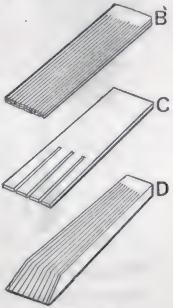


Fig. 71.

Rotating brushes consisting of metal discs are sometimes employed. Copper is almost universally used for the brushes of dynamo-electric machines.

The brush shown at B, Fig. 71, is formed of copper wires, soldered together at the non-bearing end. A copper plate, slit at the bearing end, is shown at C, and bundles of copper plates, soldered together at the non-bearing end, are shown at D.

The brushes should bear against the commutator cylinder with sufficient force to prevent jumping, and consequent burning, and yet not so hard as to cause excessive wear.

Brushes, Lead of —— —The angle through which the brushes of a dynamo-electric machine must be moved forwards, or in the direction of rotation, in order to diminish sparking and to get the best output from the dynamo.

The necessity for the lead arises from the counter magnetism of the armature, and the magnetic lag of its iron core. (See *Angle of Lead.*)

Brushes, Scratch—— —Brushes made of wire or stiff bristles, etc., suitable for cleaning the surfaces of metallic objects before placing them in the plating bath.

These brushes are of various shapes and are provided with wires or bristles of varying coarseness.

Buoy, Electric —— —A buoy, on which luminous electric signals are displayed.

Bunsen's Voltaic Cell.—(See *Cell, Voltaic.*)

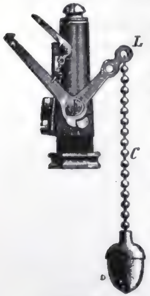


Fig. 72.

Burner, Electric —— —A gas-burner whose gas-jet is electrically ignited.

On pulling the pendant C, Fig. 72, a spark from a spark coil ignites the gas. On pulling the slide the gas is turned off. (See *Argand Burner.*)

Burner, Automatic Electric —— —An electric device for either turning on the gas and lighting it, or for turning it off.

One push-button, usually a white one, turns the gas on and lights it by means of a succession of sparks from a spark coil. Another push-button, usually a black one, turns the gas off. Automatic burners are also made with a single button.

Burglar Alarm.—(See *Alarm, Electric, Burglar.*)

Burnetizing.—A method adopted for the preservation of wooden telegraph poles by injecting a solution of zinc chloride into the pores of the wood. (See *Poles, Telegraphic.*)

Burning at Commutator of Dynamo.—An arcing at the brushes of a dynamo-electric machine, due to their imperfect contact, or improper position, which results in loss of energy and destruction of the commutator segments.

Butt Joint.—(See *Joint, Butt.*)

Button, Push ——— --A device for closing an electric circuit by the movement of a button.

A button, when pushed by the hand, closes a contact, and thus completes a circuit in which some electro-receptive device is placed. This circuit is opened by a spring, on the removal of the pressure. Some forms of push-buttons are shown in Figs. 73 and *73a*.

Fig. 73.

Fig. 73a.

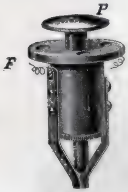


Fig. 74.

A *floor-push* for dining-rooms and offices is shown in Fig. 74.

B. W. G.—A contraction for Birmingham Wire Gauge. (See *Wire Gauge.*)

Buzzer, Electric ——— —A call, not as loud as that of a bell, produced by an automatic make and break. (See *Alarms, Electric.*)

Cable Armor—(See *Armor of Cable.*)

Cable Clip.—(See *Cable Hanger.*)

Cable Core.—(See *Core of Cable.*)

Cable, Aerial ——— —A cable for telegraphic or telephonic communication, suspended in the air from suitable poles.

Cable, Electric ——— —A conductor containing either a single conductor, or two or more separately insulated electric conductors.

Strictly speaking, the word cable should be limited to the case of more than a single conductor. Usage, however, sanctions the employment of the word to indicate a single insulated conductor.

The conducting wire may consist of a single wire, of a number of separate wires electrically connected, or of a number of separate wires insulated from one another.

Fig. 75.

An electric cable consists of the following parts, viz. :

(1) The conducting wire or *core.*

(2) The insulating material for separating the several wires, and

(3) An *armor* or protecting covering, consisting of strands of iron wire, or of a metallic coating or covering of lead.

As to their position, cables are, *aerial*, *submarine*, or *underground.* As to their purpose, they are *telegraphic*, *telephonic*, or *electric light* and *power cables.*

Fig. 75 shows a form of submarine cable in which the armor is formed of strands of iron wire.

Cablegram.—A message received by means of a submarine telegraphic cable.

Cable Hanger.—A hanger or hook, suitably secured to the cable, and designed to sustain its weight by intermediately supporting it on iron or steel wires.

A cable hanger, or *cable clip*, is shown in Fig. 76.

The weight per foot of an aerial cable is generally so great that the poles or supports would require to be very near together, unless the device of intermediate supports, by means of cable clips, were adopted

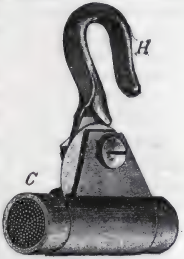


Fig. 76.

Cable Serving.—Strands of tarred hemp or jute, wrapped around the insulated core of a cable, to protect it from the pressure of the metallic armor.

Cables, Submarine —— —Cables designed for use under water.

These are either *shallow-water*, or *deep-sea cables.* Gutta-percha answers admirably for the insulating material of the core. Various other insulators are also used.

Strands of tarred hemp or jute, known as the *cable-serving*, are wrapped around the insulated core, to protect it from the pressure of the galvanized iron wire armor afterwards put on. To prevent corrosion of the iron wire, it is covered with tarred hemp, galvanized, or otherwise coated.

Cables, Underground —— —Cables designed for use underground.

These are either placed directly in the ground, or in *conduits*, or *subways*, especially prepared to receive them. (See *Conduit, Electric Underground. Subway, Electric.*)

Calibration, Absolute and Relative —— of Instrument.—The determination of the absolute or the rela-

tive values of the reading of an *electrometer*, *galvanometer*, *voltmeter*, *ampèremeter*, or other similar instrument.

The calibration of a galvanometer, for example, consists in the determination of the law that governs its different deflections, and by which is obtained in ampères, either the absolute or the relative current required to produce such deflections.

For various methods of calibration, see standard works on Electrical Testing, or on Electricity.

Calibration, Invariable ——— of Galvanometer.—In galvanometers with absolute calibration, a method for preventing the occurrence of variations in the intensity of the field of the galvanometer, due to the neighborhood of masses of iron, etc.

Callaud Voltaic Cell.—(See *Cell, Voltaic.*)

Call-Bell, Electric ————(See *Alarm, Electric. Bell-Call, Electric.*)

Caloric.—A term formerly applied to the fluid that was believed to be the cause or essence of heat.

The use of the word caloric at the present time is very unscientific, since heat is now known to be an effect and not a material thing. (See *Heat.*)

Calorie, or Calory.—A heat unit.

There are two calories, the small and the large calorie.

The amount of heat required to raise the temperature of one gramme of water, 1° C. is called the *small calorie.*

Sometimes the term is used to mean the amount of heat required to raise 1,000 grammes of water 1° C. This is called the *large calorie.* The first usage of the word is the commonest.

Calorescence.—The transformation of invisible heat-rays into luminous rays, when received by certain solid substances.

The term was proposed by Tyndall. The light and heat from a voltaic arc are passed through a hollow glass lens filled with a solution of iodine in bisulphide of carbon.

This solution is opaque to light but quite transparent to heat.

If a piece of charred paper, or thin platinum foil, is placed in the *focus* of these invisible rays, it will be heated to brilliant incandescence. (See *Focus.*)

Calorimeter.—An instrument for measuring the quantity of heat possessed by a given weight or volume of a body at a given temperature.

Thermometers measure temperature only. A thermometer plunged in a cup full of boiling water shows the same temperature that it would in a tub full of boiling water. The quantity of heat present in the two cases is of course greatly different and can be measured by calorimeters only.

Various forms of Calorimeters are employed.

In order to determine the quantity of heat in a given weight of any body, this weight may be heated to a definite temperature, such as the boiling point of water, and placed in a vessel containing ice, and the quantity of ice melted by the body in cooling to the temperature of the ice, is determined by measuring the amount of water derived from the melting of the ice. Care must be observed to avoid the melting of the ice by external heat.

In this way the amount of heat required to raise the temperature of a given weight of a body a certain number of degrees, or the capacity of the body for heat, may be compared with the capacity of an equal weight of water. This ratio is called the Specific Heat. (See *Heat, Specific.*)

The heat energy, present in a given weight of any substance at a given temperature, can be determined by means of a calorimeter; for, since a pound of water heated 1° F. absorbs an amount of energy equal to 772 foot-pounds, the energy can be readily calculated if the number of pounds of water and the number of degrees of temperature are known. (See *Mechanical Equivalent of Heat.*)

Calorimeter, Electric — —An instrument for measuring the heat developed in a conductor, in a given time, by an electric current.

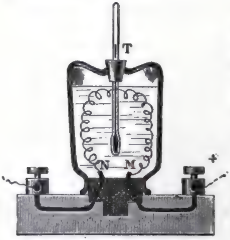


Fig. 77.

A vessel containing water, is provided with a thermometer T, Fig. 77. The electric current passes for a measured time through a wire N M, immersed in the liquid.

The quantity of heat is determined from the increase of temperature, and the weight of the water.

According to Joule, the number of *heat units* (See *Heat Units, English*) developed in a conductor by an electric current is proportional,

1. To the Resistance of the Conductor.
2. To the Square of the Current passing.
3. To the Time the current is passing.

The heating power of a current is as the square of the current only when the resistance remains the same. (See *Heat, Electric.*)

Calorimetric Photometer.—(See *Photometer, Calorimetric.*)

Candle, Electric — —A term applied to the Jablochkoff candle, and other similar devices.


Fig. 78.

The Jablochkoff electric candle consists of two parallel carbons, separated by a layer of kaolin or other heat-resisting insulating material, as shown in Fig. 78. The current is passed into and out of the carbons at one end of the candle, and forms a voltaic arc at the other end. In order to start the arc, a thin strip called the *igniter*, consisting of a mixture of some readily ignitable substance, connects the upper ends of the carbons.

An alternating current is generally employed with these candles, thus avoiding the difficulty which would otherwise occur from the more rapid consumption of the positive than the negative carbon. (See *Current, Alternating.*)

Candle, Foot —— —A unit of illumination equal to the illumination produced by a standard candle at the distance of one foot. Proposed by Hering.

According to this unit, the illumination produced by a standard candle at the distance of two feet would be but the one-fourth of a foot-candle ; at three feet, the one-ninth of a foot-candle, etc.

The advantage of the proposed standard lies in the fact that knowing the illumination in foot-candles required for the particular work to be done, it is easy to calculate the position and intensity of the lights required to produce the illumination.

Candle, Metre —— —The illumination produced by a standard candle at the distance of one metre.

Candle, Standard —— —A candle of definite composition which, with a given consumption in a given time, will produce a light of a fixed and definite brightness.

A candle which burns 120 grains of spermacetti wax per hour, or 2 grains per minute, will give an illumination equal to *one standard candle.*

Candle, A——, or, Unit of Photometric Measurement.—The unit of photometric intensity.

Such a light as would be produced by the consumption of two grains of a standard candle per minute.

An electric lamp of 16 candle-power, or one of 2,000 candle-power, is a light that gives respectively 16 or 2,000 times as bright a light as that of one standard candle.

Capacity, Dielectric —— —(See *Dielectric Capacity.*)

Capacity, Electrostatic—— —The ability of a con-

ductor or condenser to hold a certain quantity of electricity at a certain potential.

The electrostatic capacity of a conductor, or of a *condenser*, is measured by the quantity of electricity which must be given it as a charge, in order to raise its potential a certain amount. (See *Condenser. Potential.*) In this respect the electrostatic capacity of a conductor is not unlike the capacity of a vessel filled with a liquid or gas. A certain quantity of liquid will fill a vessel to a level dependent on the size or capacity of the vessel. In the same manner a given quantity of electricity will produce, in a conductor or condenser, a certain difference of electric level dependent on the electrical capacity of the conductor or condenser.

Or, the quantity of gas that can be forced into a vessel depends on the size of the vessel and the pressure with which it is forced in. A tension or pressure is thus produced by the gas on the walls of the vessel that is greater, the smaller the size of the vessel, and the greater the quantity forced in.

In the same manner, the smaller the capacity of a conductor, the smaller is the charge required to raise it to a given potential, or the higher the potential a given charge will raise it.

The capacity K, of a conductor or condenser, is therefore directly proportional to the charge Q, and inversely proportional to the potential V, or

$$K = \frac{Q}{V} .$$

From which we obtain $Q = KV$; *or,*

The quantity of electricity, required to charge a conductor or condenser to a given potential, is equal to the capacity of the conductor or condenser multiplied by the potential through which it is raised.

Capacity, Electrostatic —— Unit of ——; The Farad.—A conductor or condenser of such a capacity that

an electro-motive force of one volt will charge it with a quantity of electricity equal to one coulomb. (See *Farad.*)

Capacity of Polarization of a Voltaic Cell.—The quantity of electricity required to be discharged by a voltaic cell in order to produce a given polarization. (See *Cell, Voltaic. Polarization of Negative Plate.*)

During the discharge of a voltaic battery, an electro-motive force is gradually set up that is opposed to that of the battery. The quantity of electricity required to produce a given polarization, depends, of course, on the condition and size of the plates. Such a quantity is called the Capacity of Polarization.

Capacity of a Telegraph Line or Cable.—The ability of a wire or cable to permit a certain quantity of electricity to be passed into it before acquiring a given difference of potential.

Before a telegraph line or cable can transmit a signal to its further end, its difference of potential must be raised to a definite amount dependent on the character of the instruments and the nature of the system.

The first effect of a given quantity of electricity being passed into a line, is to produce an accumulation of electricity on the line, similar to the charge in a *condenser.* Cables especially act as condensers, and from the high specific inductive capacity of the insulating materials employed, permit considerable induction to take place between the core, and the metallic armor or sheathing, or the ground.

The capacity of a cable depends on the capacity of the wire; *i.e.*, on its length and surface, on the specific inductive capacity of its insulation, and its neighborhood to the earth, or to other conducting wires, casings, armors, or metallic coatings. Submarine or underground cables therefore have a greater capacity than air lines.

This accumulation of electricity produces a *retardation* in the speed of signaling, because the wire must be charged before the signal is received at the distant end, and discharged

or neutralized before a current can be sent in the reverse direction. This latter may be done by connecting each end to earth, or by the action of the reverse current itself.

The smaller the electrostatic capacity of a cable, therefore, the greater the speed of signaling. (See *Retardation.*)

Capacity, Specific Inductive ——; Dielectric Capacity, or Dieletric Constant.—The ability of a dielectric to permit induction to take place through its mass, as compared with the ability possessed by a mass of air of the same dimensions and thickness, under precisely similar conditions.

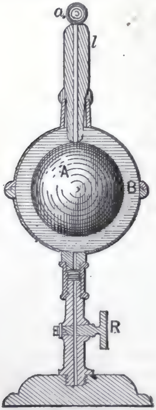


Fig. 79.

The inductive capacity of a dielectric is compared with that of air.

According to Gordon and others, the specific inductive capacities of a few substances compared with air, are as follows:

Air	1.00
Glass	3.013 to 3.258
Ebonite	2.284
Gutta-percha	2.462
India rubber	2.220 to 2.497
Paraffin (solid)	1.994
Shellac	2.740
Sulphur	2.580
Turpentine	2.160
Petroleum	2.030 to 2.070
Carbon bisulphide	1.810
Vacuum	0.99941
Hydrogen	0.99967
Carbonic acid	1.00036

Faraday, who proposed the term *specific inductive capacity*, employed in his experiments a condenser consisting of a metallic sphere A, Fig. 79, placed inside a large hollow sphere B.

The concentric space between A and B was filled with the substance whose specific inductive capacity was to be determined.

Capillarity.—The elevation or depression of liquids in tubes of small internal diameter.

The liquid is elevated when it wets the walls, and depressed when it does not wet the walls of the tube.

The phenomena of capillarity are due to the molecular attractions existing between the molecules of the liquid for one another, and the mutual attraction between the molecules of the liquid and those of the walls of the tube.

Capillarity, Effects of, on Battery Cells.—Disturbing effects of the proper action of a voltaic battery caused by capillary action.

These effects are as follows, viz.:

(1) Creeping, or Efflorescence of salts. (See *Creeping. Efflorescence.*)

(2) Oxidation of Contacts and consequent introduction of increased resistance into the battery circuit. The liquid enters the capillary spaces between the contact surfaces and oxidizes them.

Capillary Electrometer.—An electrometer in which

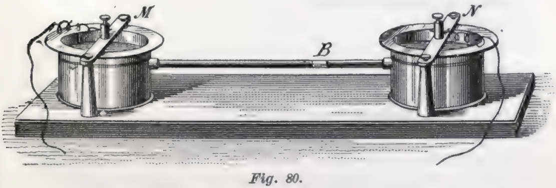


Fig. 80.

difference of potential is measured by the movements of a drop of sulphuric acid in a horizontal tube filled with mercury.

The horizontal glass tube with a drop of acid at B, is shown in

Fig. 80. The ends of the tube are connected with two vessels, M and N, filled with mercury. If a current be passed through the tube, a movement of the drop *towards the negative pole* will be observed. Where the electro-motive force does not exceed one volt, the amount of the movement is proportional to the electro-motive force.

Carbon.—An elementary substance which occurs naturally in three distinct allotropic forms, viz.: charcoal, graphite and the diamond. (See *Allotropy.*)

Carbon, Artificial—— —Carbon obtained by the carbonization of a mixture of pulverized carbon with different carbonizable liquids.

Powdered coke, or gas-retort carbon, sometimes mixed with lamp-black or charcoal, is made into a stiff dough with molasses, tar, or any other hydro-carbon liquid. The mixture is moulded into rods, pencils, plates, bars or other desired shapes by the pressure of a powerful hydraulic press. After drying, the carbons are placed in crucibles and covered with lamp-black, or powdered plumbago, and raised to an intense heat at which they are maintained for several hours. By the carbonization of the hydro-carbon liquid the carbon paste becomes strongly coherent, and by the action of the heat its conducting power increases.

To give increased density after baking, the carbons are sometimes soaked in a hydro-carbon liquid, and subjected to a re-baking.

Carbon Electrodes for Arc Lamps.—Rods of artificial carbon employed in arc lamps.

Carbons for arc lamps are generally copper-coated, so as to somewhat decrease their resistance, and to ensure a more uniform consumption. They are sometimes provided with a central *core* of soft carbon, which fixes the position of the arc and thus ensures a steadier light. (See *Carbons, Cored.*)

Carbon Holders for Arc Lamps.—Various clamping devices for holding the carbon electrodes of an arc lamp in the lamp rods.

Carbon Telephone Transmitter.—A telephone transmitter consisting of a button of compressible carbon.

The sound-waves impart their to-and-fro-movements to the transmitting diapraghm, and this to the carbon button thus varying its resistance by pressure. This button is placed in circuit with the battery and induction coil. (See *Telephone.*)

Carbonic Acid Gas.—A gaseous substance formed by the union of one atom of carbon with two atoms of oxygen.

Carbonic acid gas is formed by the combustion of carbon in a full supply of air.

Carbonization, Processes of—— —Means for suitably carbonizing carbonizable material.

Carbonizable material is placed in suitably shaped boxes, covered with powdered plumbago or lamp-black, and subjected to the prolonged action of intense heat while out of contact with air.

The electrical conducting power of the carbon which results from this process is increased by the action of the heat, and, probably, also by the deposit in the mass of the carbon, of carbon resulting from the subsequent decomposition of the hydro-carbon gases produced during carbonization.

When the carbonization is for the purpose of producing conductors for incandescent lamps, in order to obtain the uniformity of conducting power, electrical homogeneity, purity and high refractory power requisite, selected fibrous material, cut or shaped in at least one dimension prior to carbonization, must be taken, and subjected to as nearly uniform carbonization as possible.

Carbonized Cloth for High Resistances.—Discs of cloth carbonized by heating them to an exceedingly high temperature in a vacuum, or out of contact with air.

After carbonization the discs retain their flexibility and elasticity and serve admirably for high resistances. When piled together and placed in glass tubes, they form excellent variable resistances when subjected to varying pressure.

Carbons, Cored —— for Arc Lamps.—A cylindrical carbon electrode that is moulded around a central core of charcoal, or other softer carbon.

These carbons, it is claimed, render the arc light steadier, by maintaining the arc always at the softer carbon, and hence at the central point of the electrode.

A core of harder carbon, or other refractory material, is sometimes provided for the negative carbon.

Carbons, Concentric, Cylindrical———A cylindrical rod of carbon placed inside a hollow cylinder of carbon but separated from it by an air space, or by some other insulating, refractory material.

Sometimes Jablochkoff candles are made with a solid cylindrical electrode, concentrically placed in a hollow cylindrical carbon.

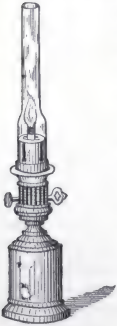


Fig. 81.

Carcel.—The light emitted by a lamp burning 42 grammes of pure colza oil per hour, with a flame 40 millimetres in height.

One carcel = 9.5 to 9.6 standard candles.

Carcel Lamp.—An oil lamp employed in France as a photometric standard.

Fig. 81 shows a form of carcel lamp.

Carcel Standard Gas Jet.—A lighted gas jet employed for determining the candle power of gas by measuring the height of a jet of gas burning under a given pressure, and used in connection with the light of a larger gas burner, burning under similar conditions, for the photometric measurement of electric lights.

In Fig. 82, is shown a section of a *seven-carcel standard gas jet*, and, in Fig. 83, a section of a "*candle burner*," connected with the same service pipe. The gas for both burners is received in a chamber from whence it passes by an opening to the burner under the constant pressure obtained by the weight of the bell C, and the tube A. The burner shown in Fig. 83, which is used as the standard of comparison, will give a candle power determined from the height of the jet of the burning gas. This height is measured in millimetres by a movable circular screen.

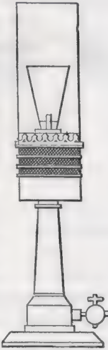


Fig. 82.

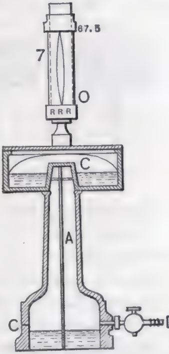


Fig. 83.

The determination of the candle power of gas by means of a jet photometer is only approximately correct, unless many precautions are taken.

Card, Compass ——— —A card used in a mariner's compass, on which are marked the points of the compass. (See *Compass Card. Azimuth Compass.*)

Cascade, Charging Leyden Jars by——— —A device for charging jars or condensers by means of the free electricity liberated by induction in one coating, when a charge is passed into the other coating.

The jars are placed as shown in Fig. 84, with the inside coating of one jar connected with the outside coating of the one next it. There is in reality no increase in the entire charge obtained by the use of charging by cascade since the sum of the

charges given to the separate jars is equal to the same charge given to a single jar separately charged.

The energy of the discharge in cascade can be shown to be less than that of the same charge when confined to a single jar.

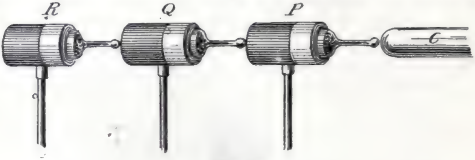


Fig. 84.

Cathion.—A term sometimes used instead of Kation. More correctly written Kathion. (See *Kathion.*)

Cathode.—A term sometimes used instead of Kathode. More correctly written Kathode. (See *Kathode.*)

Caoutchouc, or India-rubber.—A resinous substance obtained from the milky juices of certain tropical trees.

Caoutchouc possesses high powers of electric insulation.

Cautery, Electric or Galvano-Cautery.—In electro therapeutics, the application of platinum wires of various shapes, heated to incandescence by the electric current, and used, in place of a knife, for removing diseased growths, or for stopping hemorrhages.

The operation, though painful during application, is afterwards less painful than that with a knife, since secondary hemorrhage seldom occurs, and the wound rapidly heals.

Galvano-cautery is applicable in cases where the knife would be inadmissible owing to the situation of the parts or their surroundings.

Cell, Voltaic —— —The combination of two metals, or of a metal and a metalloid, which when dipped into a liquid or liquids called electrolytes, and connected outside the liquid by a conductor, will produce a current of electricity.

Different liquids or gases may take the place of the two metals, or of the metal and metalloid. (See *Gas Battery.*)

Plates of zinc and copper dipped into a solution of sulphuric acid and water, and connected outside the liquid by a conductor form a simple voltaic cell.

If the zinc be of ordinary commercial purity, and is not connected outside the liquid by a conductor, the following phenomena occur :

(1) The sulphuric acid or hydrogen sulphate, H_2SO_4, is decomposed, zinc sulphate, $ZnSO_4$, being formed, and hydrogen, H_2, liberated.

(2) The hydrogen is liberated mainly at the surface of the zinc plate.

(3) The entire mass of the liquid becomes heated.

If, however, the plates are connected outside the liquid by a conductor of electricity, then the phenomena change and are as follows, viz. :

(1) The sulphuric acid is decomposed as before, but

(2) The hydrogen is liberated at the surface of the copper plate only.

(3) The heat no longer appears in the liquid only, but also in all parts of the circuit, and

(4) An electric current now flows through the entire circuit, *and will continue so to flow* as long as there is any sulphuric acid to be decomposed, or zinc with which to form zinc sulphate.

The energy which previously appeared as heat only, now appears as electric energy.

Therefore, although the mere contact of the two metals with the liquid will produce a difference of potential, it is *the chemical potential energy*, which become *kinetic* during the chemical combination, that supplies the energy required to maintain the electric current. (See *Energy. Kinetic Potential.*

Simple Voltaic Cell.—A simple voltaic cell consists of two

plates of different metals, or of a metal and a metalloid (or of two gases, or two liquids, or of a liquid and a gas), each of which is called a *voltaic element*, and which, taken together, form what is called a *voltaic couple.*

The *voltaic couple* dips into a liquid called an *electrolyte*, which, as it transmits the electric current, is decomposed by it. The elements are connected outside the electrolyte by any conducting material.

Direction of the Current.—In any voltaic cell the current is assumed to flow *through the liquid*, from the metal most acted on to the metal least acted on, and *outside the liquid*, through the outside circuit, from the metal least acted on to the metal most acted on.

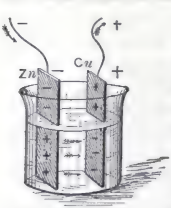


Fig. 85.

In Fig. 85, a *zinc-copper* voltaic couple is shown, immersed in dilute sulphuric acid. Here, since the zinc is dissolved by the sulphuric acid, the zinc is positive, and the copper negative in the liquid. The zinc and copper are of opposite polarities out of the liquid.

It will of course be understood that in the above sketch the current flows only on the completion of the circuit outside the cell, that is, when the conductors attached to the zinc and copper plates are electrically connected.

Amalgamation of the Zinc Plate.—When zinc is used for the positive element, it will, unless chemically pure, be dissolved by the electrolyte when the circuit is open, or will be irregularly dissolved while the circuit is closed, producing currents in little closed circuits from minute voltaic couples formed by the zinc and such impurities as *carbon, lead,* or *iron,* etc., always found in commercial zinc. (See, *Action, Local.*) As it is practically impossible to obtain chemically pure zinc, it is necessary to *amalgamate* the zinc plate, that is, to cover

it with a thin layer of zinc amalgam. (See *Zinc, Amalgamation of.*)

Polarization of the Negative Plate.—Since the evolved hydrogen appears at the surface of the negative plate, after a while the surface of this plate, unless means are adopted to avoid it, will become coated with a film of hydrogen gas, or as it is technically called, will become polarized. (See *Polarization of Voltaic Cell.*)

The effect of this polarization is to cause a falling off or weakening of the current produced by the battery, due to the formation of a *counter-electro-motive force* produced by the hydrogen-covered plate; that is to say, the negative plate, now being covered with hydrogen, a very highly electro-positive element, tends to produce a current in a direction opposed to that of the cell proper. (See *Counter-Electro-Motive Force.*)

In the case of *storage cells*, this counter-electro-motive force is employed as the source of *secondary currents.* (See *Storage of Electricity. Storage Cells.*)

In order to avoid the effects of polarization in voltaic cells, and thus ensure constancy of current, the bubbles of gas at the negative plate are mechanically carried off either by roughening its surface, by forcing the electrolyte against the plate as by shaking, or by a stream of air; or else the negative plate is surrounded by some liquid which will remove the hydrogen, by entering into combination with it. (See *Polarization of Voltaic Cell.*)

Voltaic cells are therefore divided into cells with one or with two fluids, or electrolytes, or, into

(1) Single-fluid cells, and

(2) Double-fluid cells.

Very many forms of voltaic cells have been devised. The following are among the more important, viz.:

SINGLE-FLUID CELLS.

The Grenet, Poggendorff, or Bichromate Cell.—A *zinc-carbon* couple used with an electrolyte known as *electropoion*, a

solution of bichromate of potash and sulphuric acid in water. (See *Electropoion Liquid.*)

The zinc, Fig. 86, is amalgamated and placed between two carbon plates. The terminals connected with the zinc and carbon are respectively *negative* and *positive*. In the form shown in the figure, the zinc plate can be lifted out of the liquid when the cell is not in action.

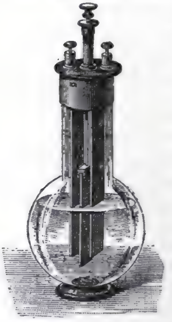


Fig. 86.

The bichromate cell is excellent for purposes requiring strong currents, where long action is not necessary. As this cell readily polarizes, it cannot be advantageously employed for any considerable period of time. It becomes depolarized, however, when left for some time on open circuit.

The following chemical reaction takes place when the cell is furnishing current, viz.:

$K_2Cr_2O_7+7H_2SO_4+3Zn=K_2SO_4+3ZnSO_4+Cr_23(SO_4)+7H_2O.$

This cell gives an electro-motive force of about 1.987 volts.

The Smee Cell.—A *zinc-silver* couple used with an electrolyte of dilute sulphuric acid, H_2SO_4.

The silver plate is covered with a rough coating of metallic platinum, in the condition known as *platinum black*. (See *Platinum Black.*) This cell was formerly extensively employed in *electro-metallurgy* but it is now replaced by *dynamo-electric machines.* (See *Electro-Metallurgy. Dynamo-Electric Machine.*)

A *zinc-carbon* couple is sometimes used to replace the *zinc-silver* couple. A couple of *zinc-lead* is also used, though not very advantageously.

The Zinc-Copper Cell.—A *zinc-copper* couple used with dilute sulphuric acid.

This was one of the earliest forms of voltaic cells.

In the zinc-silver, or the zinc-copper couple, the chemical reaction that takes place when the cell is furnishing current is as follows, viz.:

$$Zn + H_2\,SO_4 = Zn\,SO_4 + H_2.$$

The Smee cell gives an electro-motive force of about .65 volts.

DOUBLE-FLUID CELLS.

Grove's Cell.—A *zinc-platinum* couple the elements of which are used with electrolytes of sulphuric and nitric acids respectively.

The zinc, Z, Fig. 87, is amalgamated and placed into dilute sulphuric acid, and the platinum, P, into strong *nitric acid* ($H\,NO_3$), placed in a *porous cell* to separate it from the sulphuric acid. (See *Porous Cells.*) In this cell the current is moderately constant, since the polarization of the platinum plate is prevented by the nitric acid that oxydizes and thus removes the hydrogen that tends to be liberated at its surface. The constancy of the current is not maintained for any considerable time, since the two liquids are rapidly decomposed, or consumed, zinc sulphate forming in the sulphuric acid, and water in the nitric acid.

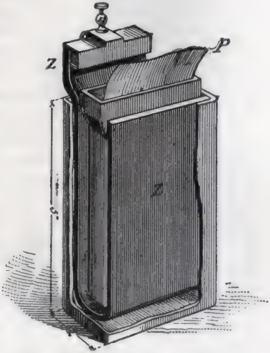


Fig. 87.

The chemical reactions are as follows, viz.:

$$Zn + H_2SO_4 = Zn\,SO_4 + H_2;$$
$$6H + 2H\,NO_3 = 4H_2O + 2NO;$$
$$2NO + O_2 = N_2O_4.$$

This cell gives an electro-motive force of 1.93 volts.

Bunsen's Cell.—A zinc-carbon couple, the elements of which are immersed respectively in electrolytes of dilute sulphuric and strong nitric acids.

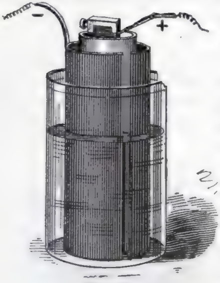


Fig. 88.

Bunsen's cell is the same as Grove's except that the platinum is replaced by carbon. The zinc surrounds the porous cell containing the carbon. The polarity is as indicated in Fig. 88.

The Bunsen cell gives an electro-motive force of about 1.96 volts.

Daniell's Cell.—A *zinc-copper* couple, the elements of which are used with electrolytes of dilute sulphuric acid, and saturated solution of copper sulphate respectively.

The copper element is made in the form of á cylinder *c*, Fig. 89, and is placed in a porous cell. The copper cylinder is provided with a wire basket near the top, filled with crystals of blue vitriol, so as to maintain the strength of the solution while the cell is in use. The zinc is in the shape of a cylinder and is placed so as to surround the porous cell. This cell gives a nearly constant electro-motive force.

Fig. 89.

The constancy of its action depends on the fact that for every molecule of sulphuric acid decomposed in the outer cell, an additional molecule

of sulphuric acid is supplied by the decomposition of a molecule of copper sulphate in the inner cell. This will be better understood from the following reactions which take place, viz.:

$$Zn + H_2\,SO_4 = Zn\,SO_4 + H_2$$
$$H_2 + Cu\,SO_4 = H_2\,SO_4 + Cu.$$

The $H_2\,SO_4$, thus formed in the inner cell, passes through the porous cell, and the copper is deposited on the surface of the copper plate.

The Daniell's cell gives an electro-motive force of about 1.072 volts.

A serious objection to this form of cell arises from the fact that the copper is gradually deposited over the surface and in the pores of the porous cell, thus greatly varying its resistance.

Callaud's Gravity Cell.—A zinc-copper couple, the elements of which are employed with electrolytes of dilute sulphuric acid, or dilute zinc sulphate, and a concentrated solution of copper sulphate respectively. This cell was devised in order to avoid the use of a porous cell. As its name indicates, the two fluids are separated from each other by gravity.

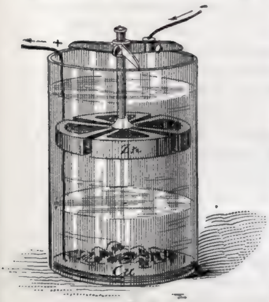


Fig. 90.

The copper plate is the lower plate, and is surrounded by crystals of copper sulphate. The zinc, generally in the form of an open wheel, or crowfoot, is suspended near the top of the liquid, as shown in Fig. 90.

The reactions are the same as in the Daniell cell.

A dilute solution of zinc sulphate is generally used to replace the dilute sulphuric acid. It gives a somewhat lower electromotive force, but ensures a greater constancy for the cell.

The Leclanché Cell.—A zinc-carbon couple the elements of which are used with a solution of sal-ammoniac, and a finely divided layer of black-oxide of manganese respectively.

The zinc is in the form of a slender rod and dips into a saturated solution of *sal-ammoniac*, NH_4 Cl.

The negative element consists of a plate of carbon, C, Fig. 91, placed in a porous cell, in which is a mixture of black oxide of manganese and broken gas-retort carbon, tightly packed around the carbon plate. By this means a greatly extended surface of carbon surrounded by black oxide of manganese, $Mn\ O_2$, is secured. The entire outer jar, and the spaces inside the porous cell are filled with the solution of sal-ammoniac. This cell, though containing but a single fluid, belongs, in reality, to the class of *double-fluid cells*, being one in which the negative element is surrounded by an oxidizable substance, the black oxide of manganese, which replaces the nitric acid, or copper sulphate in the preceding cell.

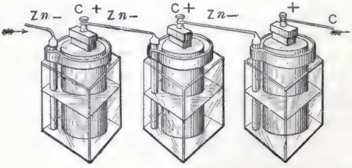


Fig. 91.

The reactions are as follows, viz. :

$$Zn + 2(NH_4\ Cl) = Zn\ Cl_2 + 2NH_3 + H_2.$$

The Zn Cl_2 and NH_3 react as follows :

$$Zn\ Cl_2 + 2(NH_3) = (2NH_3)\ Zn\ Cl_2 + H_2.$$

$$2H + 2(Mn_2\ O_2) = H_2\ O + Mn_2\ O_3,$$

or, possibly, $4H + 3Mn\ O_2 = Mn_3\ O_4 + 2H_2\ O.$

The Leclanché cell gives an electro-motive force of about 1.47 volts. It rapidly polarizes, and cannot, therefore, give a steady current for any prolonged time. When left on open circuit, however, it rapidly depolarizes.

Of all the voltaic cells that have been devised two only, viz., the *Gravity* and the *Leclanché*, have continued until now in very general use. The gravity cell being used on *closed-circuit lines* and the *Leclanché* on *open-circuit lines;* the former being the best suited of all cells to furnish *continuous constant* currents employed in most systems of telegraphy, and the latter for furnishing the intermittent currents required for ringing bells, operating annunciators, or for similar work.

The Siemens-Halske Cell.—A *zinc-copper* couple the elements of which are employed with dilute sulphuric acid and saturated solution of copper sulphate respectively.

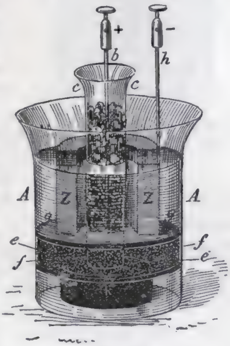


Fig. 92.

This cell is a modification of Daniell's. A ring of zinc, Z Z, Fig. 92, surrounds the glass cylinder *c*, *c*. The porous cell is replaced by a diaphragm, *f f*, of porous paper, formed by the action of sulphuric acid on a mass of paper pulp. Crystals of copper-sulphate are placed in the glass jar, *c c*, and rest on the copper plate *k*, formed of a close copper spiral. Terminals are attached at *b* and *h*. The entire cell is charged with dilute sulphuric acid. The resistance of the cell is high.

The Meidinger Cell.—A zinc-copper couple the elements of which are employed with dilute sulphuric acid, or solution of sulphate of magnesia, and strong nitric acid, respectively.

This is another modification of the Daniell cell. The *zinc-copper* couple is thus arranged: Z Z, Fig. 93, is an amalgamated zinc ring placed near the walls of the vessel, A A. The

copper element *c* is similarly placed with respect to the vessel *b b*. The glass cylinder *h* filled with crystals of copper sulphate, has a small hole in its bottom, and keeps the vessel, *b b*, supplied with saturated solution of copper sulphate. The cell is charged with dilute sulphuric acid, or a dilute solution of Epsom salts, or magnesium sulphate.

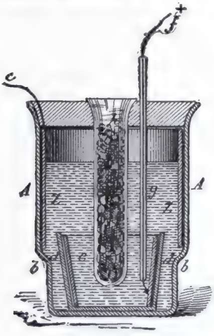


Fig. 93.

Cell, Standard Voltaic ———.—(See Standard *Voltaic Cell.*)

Cements, Insulating ———.—Various mixtures of gums, resins and other substances, possessing the ability to bind two or more substances together and yet to electrically insulate one from the other.

Centi (as a prefix).—The one hundredth of.

Centigrade Thermometer Scale.—A thermometer scale on which the freezing point of water is marked 0°, and the boiling point at 30 inches of the barometer 100°.

Centigrade degrees are indicated by a C., thus 0° C. or 100° C., to distinguish them from Fahrenheit degrees that are marked F.—(See *Thermometer.*)

Centigramme.—The hundredth of a gramme, or 1544 grains. (See *Metric System of Weights and Measures.*)

Centimetre.—A length equal to the one hundreth of a metre or .3937 inch. (See *Metric System of Weights and Measures.*)

Centimetre-Gramme-Second System, or the C. G. S. System.—A system of units of measurement in which the centimetre is adopted for the unit of the length, the

gramme for the unit of mass, and the second for the unit of time.

This is the same as the *Absolute System of Units.* (See *Absolute Units.*)

Central Station Lighting.—(See *Lighting, Central Station.*

Centre of Gravity.—(See *Gravity, Centre of.*)

Centre of Oscillation.—(See *Oscillation, Centre of.*)

Centre of Percussion.—(See *Percussion, Centre of.*)

Centrifugal Force (so called).—The force that is supposed to urge a rotating body *directly* away from the centre of rotation.

If a stone be tied to a string and whirled around, and the string break, the stone will not fly off *directly away from the centre,* but will move along the tangent to the point where it was when the string broke.

The centrifugal force in reality is the force which is represented by the tension to which the string is subjected during rotation.

Centrifugal Governor ——— —A device for maintaining constant the speed of a steam engine or other prime mover, despite sudden changes in the load, or work.

In a ball governor any increase in speed causes the balls to fly out from the centre of rotation by centrifugal force, which is utilized to control a valve or other regulating device. If the speed falls the balls move towards the centre, shifting the valve or regulating device in the opposite direction.

Chain, Molecular ——— —(See *Molecular Chain.*)

Chamber of Lamp.—The glass bulb or chamber of an incandescing electric lamp in which the incandescing conductor is placed, and which is generally maintained at a high vacuum.

Characteristic Curves.—Diagrams in which curves are employed to represent the ratio of certain varying values.

The electro-motive force generated in the armature coils of a dynamo-electric machine, when the magnetic field is of a constant intensity, is theoretically proportional to the speed of rotation. (In practice this is prevented by a number of circumstances). The relation existing between the speed and electro-motive force may be graphically represented by referring the values to two straight lines, one horizontal and the other vertical, called respectively the *axes of abscissas and ordinates.* (See *Abscissas, Axis of.*) If, in a given case, the number of revolutions are marked off along the horizontal line from the point 0, Fig. 94, in distances from 0, proportional to the number of revolutions, and the corresponding electro-motive forces are marked off along the vertical line in distances from 0, proportional to the electro-motive forces, the points where these lines intersect, will form the characteristic curve as shown for the particular case.

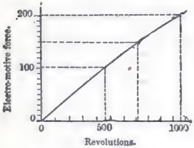


Fig. 94.

Charge, Bound and Free —— —(See *Bound and Free Charge.*)

Charge, Density of —— or Electrical Density.— The quantity of electricity at any point on a charged surface.

Coulomb used the phrase *Surface Density* to mean the quantity of electricity per unit of area at any point on a surface.

Charge, Electric —— —The quantity of electricity that exists on the surface of an insulated electrified conductor.

When such a conductor is touched by a good conductor connected with the earth, it is *discharged.*

Charge, Dissipation of —— —(See *Dissipation of Charge.*)

Charge, Distribution of —— —The variations that

exist in the density of an electrical charge at different portions of the surface of all insulated conductors except spheres.

The density of charge varies at different points of the surface of conductors of various shapes. It is uniform at all points on the surface of a sphere.

It is greatest at the extremities of the longer axis of an egg shaped body, and greater at the sharper end.

It is five times greater at the corners of a cube than at the middle of a side.

It is greatest round the edge of a circular disc.

It is greatest at the apex of a cone.

Charge, Residual ——— —The charge possessed by a charged Leyden jar a few moments after it has been disruptively discharged by the connection of its opposite coatings.

The residual charge is probably due to a species of *dielectric strain*, or a strained position of the molecules of the glass caused by the charge. Such residual charge is not present in air condensers.

Charge, Return ——— —(See *Back Stroke or Return.*)

Charging Accumulators.—Sending an electric current into a storage battery for the purpose of rendering it an electric source.

There is, strictly speaking, no accumulation of electricity in a storage battery, such for example as takes place in a condenser. (See *Storage Batteries*).

Characteristics of Sound.—The peculiarities that enable different musical sounds to be distinguished from one another.

The characteristics of musical sounds are :

(1) The *Tone or Pitch*, according t which a sound is either grave or shrill.

(2) The *Intensity or Loudness*, according to which a sound is either loud or feeble.

(3) The *Quality or Timbre*, the peculiarity which enables us

to distinguish between two sounds of the same pitch and intensity, but sounded on different instruments, as for example on a flute and on a piano.

Chemical Effect or Change.—Such a change, occasioned by chemical combination, as results in a loss of those properties or peculiarities by which the substances entering into combination are ordinarily recognized.

Black carbon, and yellow sulphur, for example, both solids, unite chemi... ly to form a transparent colorless liquid.

Chemical changes differ from physical changes, which latter can occur in a substance without the loss by it of the properties it ordinarily possesses.

Thus a sheet of vulcanite, electrified by friction, still retains its characteristic density, shape, color, etc.

Chemical Equivalent.—(See *Equivalent, Chemical.*)

Chemical Photometer.—(See *Photometers.*)

Chemical Potential Energy.—(See *Energy Atomic, or Energy Potential.*)

Chemical Recorder.—(See *Recorder, Chemical, Bain's.*)

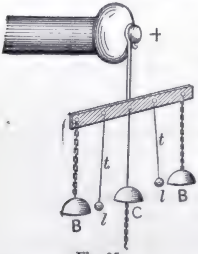


Fig. 95.

Chimes, Electric ———Bells, rung by the attractions and repulsions of electrostatic charges.

B and B, Fig. 95, are directly connected to the *prime* or *positive* conductor +, of a frictional machine. C is insulated from this conductor by means of a silk thread, but is connected with the ground by the metallic chain C. Under these circumstances the clappers, *l l*, insulated by silk threads, *t t*, are attracted to B, B, by an induced charge and repelled to C, where they lose their charge only to be again

attracted to B, B. In this way the bells will continue ringing as long as the electric machine is in operation.

Chronograph, Electric ——— —An apparatus for electrically measuring and registering small intervals of time.

Chronographs, though of a variety of forms, generally register minute intervals of time by causing a tuning fork or vibrating bar of steel, whose rate of motion is accurately known, to trace a sinuous line on a smoke blackened sheet of paper, placed on a cylinder driven by clockwork, at a uniform rate of motion. If a fork that is known to produce, say, 256 vibrations per second be used, each sinuous line will represent $\frac{1}{256}$ part of a second.

An electro-magnet is used to make marks on the line at the beginning and the end of the observation, and thus permit its duration to be measured.

Chronoscope, Electric ——— —An apparatus for electrically indicating, but not necessarily recording, small intervals of time.

The small interval of time required for a rifle ball to pass between two points may be determined by causing the ball to pierce two wire screens placed a known distance apart. As the screens are successively pierced, an electric circuit is thus made or broken, and marks are registered electrically on any apparatus moving with a known velocity.

Circle, Azimuth ——— —(See *Azimuth Circle.*)

Circle, Voltaic or Galvanic ——— —A name formerly employed for a voltaic cell or circuit.

Circuit, Astatic ——— —A circuit consisting of two closed curves enclosing equal surfaces.

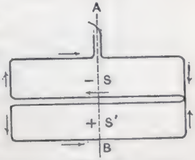


Fig. 96.

Such a circuit is not under the action of the earth's field. The circuit disposed, as shown in Fig. 96, is astatic and pro-

duces two equal and opposite fields at S and S′. (See *Magnetism, Ampère's Theory of.*)

Circuit, Broken or Opened, Made, Closed, or Completed —— —A circuit is *broken* or *opened*, when its conducting continuity is disturbed, or when the current cannot pass.

Circuit, Closed, Completed or Made —— —A circuit is *closed, completed,* or made when its conducting continuity is such that the current can pass.

Circuit, Compound —— —A circuit containing more than a single source, or more than a single electro-receptive device, or both, connected by conducting wires.

The term compound circuit is sometimes applied to a *series circuit.* (See *Circuit, Series.*) The term, however, is a bad one, and is not generally adopted.

Circuit, Earth —— —A circuit in which the ground or earth forms part of the conducting path. (See *Circuit, Varieties of.*)

Circuit, Electric —— —Literally to go around.

The path in which electricity *circulates* or passes from a given point, around or through a conducting path, back again to its starting point.

All simple circuits consist of the following parts, viz.:

(1) Of an electric *Source,* which may be a *voltaic battery* a *thermo-pile,* a *dynamo-electric machine,* or any other means for producing electricity.

(2) Of *Leads* or *Conductors* for carrying the electricity out from the source, through whatever apparatus is placed in the line, and back again to the source.

(3) Various *Electro-Receptive Devices,* such as electro-magnets, electrolytic baths, electric motors, electric heaters, etc., through which the current passes and by which they are actuated or operated.

Circuit, External ——— —That part of a circuit which is external, or outside the electric source.

Circuit, Grounded ——— —A circuit in which the ground forms part of the path through which the current passes.

As the ground is not always a good conductor, the terminals should be connected with the gas or water pipes, or with metallic plates, called *ground plates.* Such connection, or any similar ground connection is usually termed the *ground* or *earth.*

Circuit Indicator.—(See *Indicator.*)

Circuit, Internal ——— —That part of a circuit which is included within the electric source.

Circuit, Line ——— —The wire or other conductors in the main line of any telegraphic or other electric circuit. (See *Circuits, Varieties of.*)

Circuit, Local ——— —The circuit in a telegraphic system in which is placed a local battery as distinguished from a main battery. (See *Telegraph, Morse System.*)

Circuit, Main Battery ——— —A term sometimes used for Line Circuit. (See *Circuit, Line.*)

Circuit, Magnetic ——— —The path through which the lines of magnetic force pass.

All lines of force form closed circuits.

In the bar magnet, shown in Fig. 97, part of this path is through the air. In order to reduce or lower the *resistance* of a magnetic circuit, iron is often placed around the magnet. The magnet is then said to be *iron-clad.*

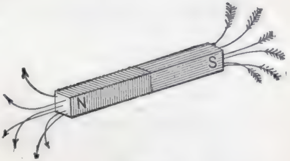


Fig. 97

The armature of a magnet lowers the magnetic resistance

by affording a better path for the lines of magnetic force than the air between the poles.

Circuit, Metallic ——— —A circuit in which the ground is not employed as any part of the path of the current.

Circuit, Multiple-Series ——— —(See *Circuits, Varieties of.*)

Circuit, Parallel or Multiple-Arc ——— —(See *Circuits, Varieties of.*)

Circuit, Simple ——— —A circuit containing a single electric source, and a single electro-receptive device, connected by a single conductor.

The term *simple circuit* is sometimes applied to a multiple arc circuit. The term is not, however, a good one, and is not in general use.

Circuit, Series ——— —(See *Circuits, Varieties of.*)

Circuit, Series-Multiple ——— —(See *Circuits, Varieties of.*)

Circuit, Shunt or Derived ——— —A circuit which forms an additional path for an electric current. (See *Shunt, or Derived Circuit.*)

Circuits, Varieties of ——— —Conducting paths provided for the passage of an electric current.

Electric circuits may be divided according to their complexity into

(1) Simple.
(2) Compound.

According to the peculiarities of their connections into

(1) Shunt or Derived.
(2) Series.
(3) Parallel or Multiple-Arc.
(4) Multiple-Series.
(5) Series-Multiple.

According to their resistance into

(1) High Resistance.

(2) Low Resistance.

According to their relation to the electric source into

(1) Internal circuits.

(2) External circuits.

According to their position in the circuit, or the work done, circuits are divided into very numerous classes; thus in telegraphy we have the following, viz. :

(1) The Line circuit.

(2) The Earth or Ground circuit.

(3) The Local Battery circuit.

(4) The Main Battery circuit, etc.

A simple circuit is one which contains but a single electric source and a single electro-receptive device, connected by a single conducting wire.

A compound circuit is one which contains more than a single electric source, or more than a single electro-receptive device, or both, connected by conducting wires.

Either the circuits, the sources, or the electro-receptive devices may be connected in series, in multiple, in multiple-series, or in series-multiple.

The most important of these are as follows :

(1) *Series circuits or connections.* Compound circuits, in which the separate circuits, or sources, are connected in one line by joining their opposite poles so that the current produced in each passes successively through the circuit.

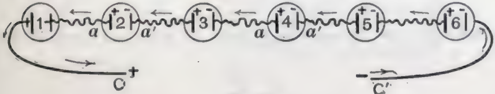


Fig. 98.

The six cells, shown in Fig. 98, are connected in series by joining the positive pole of each cell with the negative

pole of the succeeding cell, the negative and positive poles at the extreme ends being connected by any conductor.

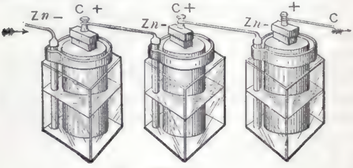


Fig. 99.

The connection of three Leclanché cells *in series* is clearly shown in Fig. 99. The carbons, C C, of the first and second cells are connected to the zincs, *Zn Zn*, of the second and third cells, thus leaving the zinc, *Zn*, of the first cell, and the carbon, C, of the third cell, as the terminals of the *battery*. The direction of the current is shown by the arrows.

The resistance of such a connection is equal to the sum of the resistances of each of the separate sources.

The electro-motive force is equal to the sum of the separate electro-motive forces.

If the electro-motive force of a single cell is equal to E, its internal resistance to r, and the resistance of the leads and electro-receptive devices to r', then the current in the circuit,

$$C = \frac{E}{r + r'} .$$

If six of such cells are coupled in series, the current becomes

$$C = \frac{6E}{6r + r'}$$

If, however, the internal resistance of each cell be so small as to be neglected, the formula becomes

$$C = \frac{6E}{r'};$$

or the current is six times as great as with one cell.

The series connection of battery cells is used on *telegraph lines*, or in all cases where a *high electro-motive force is required* in order to overcome a considerable resistance in the circuit. The instruments are also generally connected to the line in series.

This series connection was formerly called *Connection for Intensity.* The term is now abandoned.

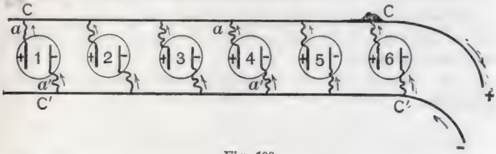


Fig. 100.

(2) *Parallel Circuit, or Multiple-Arc.*—A compound circuit in which the separate sources, or the separate electro-receptive devices, or both, are connected by one set of terminals, such as the positive, to one lead, or main positive conductor; and all the negative terminals are similarly connected to another lead, or main negative conductor, as shown in Fig. 100.

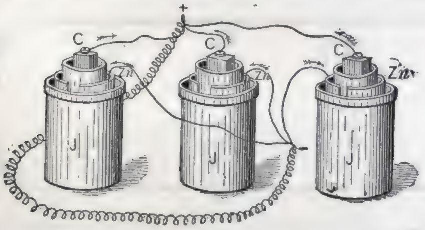


Fig. 101.

The connection of three Bunsen cells, in *multiple-arc*, is shown in Fig. 101, where the three carbons, C C C, are con-

nected together to form the positive, or + terminal of the battery, and the three zincs, *Zn Zn Zn*, are similarly connected together to form the negative, or — terminal.

The electro-motive force is the same as that of a single cell, or source. The internal resistance of the source is as much less than the resistance of any single source as the area of the combined negative or positive plates is greater than that of any single negative or positive plate; or, in other words, is less in proportion to the number of cells, or other separate sources so coupled.

In the case of the six cells above referred to, the current would be,

$$C = \frac{E}{\frac{r}{6} + r'},$$

where E, is the electro-motive force, r, the internal and r', the external resistance.

The effect of multiple connection on the internal resistance of the source is to increase the area of cross section of the liquid in the direct proportion of the number of cells added.

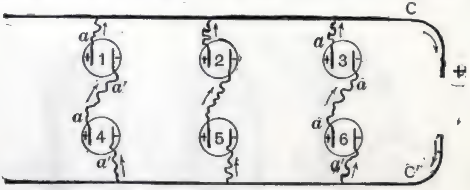


Fig. 102.

When strong or large currents of low electro-motive force are required, connections in multiple-arc are generally employed.

The multiple-arc connection was formerly called the *Connection for Quantity*. This term is now abandoned.

(3) *Multiple-Series Circuit.*—A compound circuit in which the separate sources, or electro-receptive devices, are connected in groups in *multiple-arc,* and the members of each group subsequently connected in series.

In Figs. 102 and 103, multiple-series circuits of six sources are shown. The current takes the paths indicated by the arrows. The electro-motive force of the source will be increased in proportion to the number of cells in series, and the internal resistance decreased in proportion to the number in parallel. Supposing the circuit closed by a resistance equal to r', the current would be, in Fig. 102,

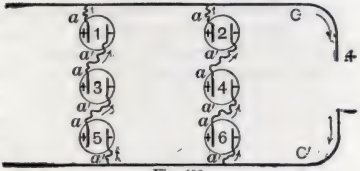


Fig. 103.

$$C = \frac{2E}{\frac{2r}{3} + r'};$$

and that in the Fig. 103,

$$C = \frac{3E}{\frac{3r}{2} + r'}.$$

(4) In *Series-Multiple;* the method adopted in the use of distribution boxes, a number of multiple groups or circuits are

Fig. 104.

connected with each other in series, as shown in Fig. 104. (See *Box, Distribution, for Arc Light Circuits.*)

In this connection the resistance of each multiple group is equal to the resistance of a single branch divided by the number of branches.

The total resistance of the circuit is equal to the *sum* of the resistances of the multiple groups.

The resistances of the separate compound circuits is as follows: Calling R′, R″, and R‴, the resistance of each of the separate parts and the joint resistance R.

(1) For the series circuit,

$$R = R' + R'' + R'''.$$

(2) For the parallel circuit,

$$R = \frac{R' \times R'' \times R'''}{R' R'' + R'' R''' + R' R'''};$$

or, what is the same thing, the conductivity of a multiple circuit is the sum of the reciprocals of the separate resistances;

$$\text{or, Conductivity} = \frac{1}{R'} + \frac{1}{R''} + \frac{1}{R'''}.$$

(3) For the multiple-series circuit, if the resistance of each circuit is r, then the total resistance

$$R = \frac{2r}{3},$$

when three are in parallel and two in series; and

$$R = \frac{3r}{2},$$

when two are in parallel and three in series.

(4) For the series-multiple circuit, calling r the resistance of each separate circuit in the five parallel circuits, then the resistance of each of the parallel groups is

$$R = \frac{r}{5};$$

and the total resistance of the three groups is

$$R = \frac{r}{5} + \frac{r}{5} + \frac{r}{5} = \frac{3r}{5}.$$

Circular Units.—Units based upon the value of the area of a circle whose diameter is unity.

Circular Units (Cross-Sections), Table of.

1 circular mil	=	.78540 square mil.
"	=	.00064514 circular millimetre.
"	=	.00050669 square millimetre.
1 square mil	=	1.2732 circular mils.
"	=	.00082141 circular millimetre.
1 circular millimetre	=	1550.1 circular mils.
"	=	1217.4 square mils.
"	=	.78540 square millimetre.
1 square millimetre	=	1973.6 circular mils.
"	=	1.2732 circular millimetres.

If d is the diameter of a circle, the area in other units is ·

If d is in mils., area in sq. millimetres	$= d^2 \times .00050669.$
d in millimetres, area in sq. mils	$= d^2 \times 1217.4.$
d in centimetres, area in sq. inches	$= d^2 \times 12174.$
d in inches, area in sq. centimetres	$= d^2 \times 5.0669.$

(*Hering.*)

Clamp or Clutch for Arc Lamps.—A clamp for gripping the lamp-rod, *i. e.*, the rod that supports the carbon electrodes of arc lamps. (See *Lamp, Electric Arc.*)

Cleats.—Insulating supports for attaching wires to the walls or ceilings of buildings.

Clepsydra, Electric——— —An instrument for measuring time by the escape of water or other liquid under electrical control.

Clocks, Electric——— —Clocks, the works of which are moved either entirely or partially by the electric current, are controlled or regulated by the electric current, or are wound thereby.

Electric clocks may therefore be divided into three classes, viz. :

(1) Those in which the works are moved entirely or partially by the electric current.

(2) Those which are controlled or regulated by the electric current.

(3) Those which are merely wound by the current.

A clock moving independently of electric power, is given a slight retardation or acceleration electrically and is thus prevented from gaining or losing time. The entire motion of the balance wheel is sometimes imparted by electricity.

An example of one of many forms of electric clock is shown in Fig. 105, where the split battery (See *Battery, Split*), P N, is connected, as shown, to the spring contacts S and S′.

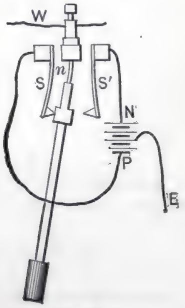


Fig. 105.

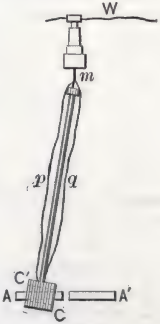


Fig. 106.

By these means currents are sent into the circuit in alternately opposite directions. The pendulum bob, Fig. 106, of the controlled clock is formed of a hollow coil of insulated wire, which encircles one or both of two permanent magnets,

A and A′, placed with their opposite poles facing each other. In this manner a slight motion forwards or backwards is imparted to the pendulum which is thus kept in time with the controlling clock.

The controlling clock is shown in Fig. 105, and the controlled clock in Fig. 106. Mercury contacts are sometimes employed in place of the springs S and S′. Induction currents may also be employed.

Clocks of non-electric action may be electrically controlled, or correctly set at certain intervals, either automatically by a central clock, or by the depression of a key operated by hand from an astronomical observatory.

In a system of *Time Telegraphy*, the controlling clock is called the *Master Clock*, and the controlled clocks the *Secondary Clocks.*

Secondary clocks are generally mere dials, containing *step-by-step movements*, for moving the hour, minute and second hands. (See *Telegraphy, Step-by-Step.*)

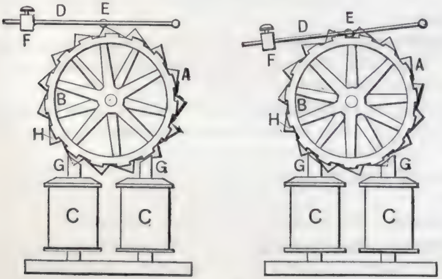


Fig. 107.

In Spellier's clock, a series of armatures H, Fig. 107, mounted on the circumference of a wheel, connected with the

escapement wheel, pass successively, with a step-by-step movement, over the poles of electro-magnets. On the completion of the circuit, they are attracted towards the magnet, and on the breaking of the circuit they are drawn away by the fall of the weight F, placed on the lever D, pivoted at E. A pulley at E, runs over the surface of a peculiarly shaped cog on the escapement wheel.

Clock, Electric Annunciator —— —A clock, the hands or works of which, at certain predetermined times, make electric contacts and thus ring bells, release drops, trace records, etc.

Clock, Master —— —The controlling clock used in a system of time telegraphy. (See *Clocks, Electric.*)

Clock-work Feed for Arc Lamps.—Arrangements of clock-work for obtaining a uniform feed motion of one or both electrodes of an arc lamp.

The clock-work is automatically thrown into or out of action by an electro-magnet, usually placed in a shunt circuit around the carbons.

Clocks, Secondary —— —The clocks in a system of time telegraphy that are controlled by the master clock. (See *Clocks, Electric.*)

Clocks, Self-Winding —— —Clocks that at regular intervals are automatically wound by the action of a small *electro-magnetic motor* contained in the clock.

Closed Circuit.—(See *Circuit, Closed, Completed or Made.*)

Closure.—The completion of an electric circuit.

Coatings, Condenser —— —The sheets of tin foil on opposite sides of a Leyden Jar or condenser, which receive the opposite charges.

Coatings, Metallic —— —Coverings or coatings of metals, deposited from solutions of metallic salts by the action of an electric current. (See *Electro-Plating.*)

Code, Cipher ——.—A code in which a number of words or phrases are represented by single words.

The message thus received requires the possession of the key to render it intelligible.

Code, Telegraphic ——.—The pre-arranged signals of any system of telegraphy. (See *Alphabet, Telegraphic; Morse, Continental.*)

Coefficient, Algebraic ——.—A number prefixed to any quantity to indicate how many times that quantity is to be taken.

The number 3, in the expression $3a$, is a coefficient and indicates that the a, is to be taken three times, as $a + a + a = 3a$.

Coefficient, Economic —— of a Dynamo Electric Machine.—The ratio between the electrical energy or the electrical horse power developed by the current produced by a dynamo, and the mechanical horse power expended in driving the dynamo.

The *Efficiency* may be the *Commercial Efficiency*, which is the useful or available energy in the external circuit divided by the total mechanical energy; or it may be the *Electrical Efficiency*, which is the available electrical energy divided by the total electrical energy.

The *Efficiency of Conversion* is the total electrical energy developed, divided by the total mechanical energy applied.

If M, equals the mechanical energy,

W, the useful or available electrical energy, and

w, the electrical energy absorbed by the machine, and

m, the *Stray Power*, or the power lost in friction, eddy currents, air friction, etc. Then, since

$\mathrm{M} = \mathrm{W} + w + m$,

Commercial Efficiency .. $= \dfrac{\mathrm{W}}{\mathrm{M}} = \dfrac{\mathrm{W}}{\mathrm{W} + w + m}$.

Electrical Efficiency .... $= \dfrac{\mathrm{W}}{\mathrm{W} + w}$.

Efficiency of Conversion $= \dfrac{\mathrm{W} + w}{\mathrm{M}} = \dfrac{\mathrm{W} + w}{\mathrm{W} + w + m}$.

Coefficient, Economic ——— —(See *Economic Coefficient.*)

Coefficient of Magnetization, or Coefficient of Magnetic Induction.—A number representing the intensity of magnetization produced in a magnetizable body as compared with the intensity of magnetization of the inducing body.

A magnetizable body, when placed in a magnetic field, concentrates the lines of magnetic force on it, or causes them to run through it. The intensity of the magnetization so produced depends, therefore,

(1) On the intensity of the magnetizing field.

(2) On the ability of the metal to concentrate the lines of force on it, that is, on the nature of the metal, or, on its *magnetic permeability.* (See *Magnetic Permeability.*)

The intensity of magnetization will therefore be equal to the product of the coefficient of magnetization, and the intensity of the magnetizing field.

The coefficient of magnetization of paramagnetic bodies is said to be positive; that of diamagnetic bodies to be negative because the former concentrate the lines of magnetic force on them, and the latter appear to repel them. (See *Paramagnetic. Diamagnetic.*)

Coefficient of Mutual Induction.—A quantity representing the relative number of lines of magnetic force which each of two neighboring electric circuits induce in the other.

Coefficients of Expansion.—The fractional increase in its dimensions of a bar or rod when heated from 32° to 33° F., or from 0° to 1° C.

The fractional increase in its length is called the *Coefficient of Linear Expansion.*

The fractional increase in its surface is called the *Coefficient of Surface Expansion.*

The fractional increase in its volume is called the *Coefficient of Cubic Expansion.*

Coefficients of Linear Expansion.—

Gold	0.000015153
Steel	0.000010972
Silver	0.000019086
Copper	0.000017173
Brass	0.000018782
Tin	0.000019376
Iron	0.000012350
Flint glass	0.000008116
Platinum	0.000009918
Lead	0.000088483
Zinc	0.000029416

(*Laplace and Lavoisier*).

Coercive, or Coercitive Force.—The power of resisting magnetization or demagnetization.

Coercive Force is sometimes called *Magnetic Retentivity.*

Hardened steel possesses great coercive force; that is, it is magnetized or demagnetized with difficulty.

Soft iron possesses very feeble coercive force.

It is on account of the feeble coercive force of the soft iron core of an electro-magnet that its main value depends, since it is thereby enabled to rapidly acquire its magnetization, on the completion of a battery circuit through its coils, and to rapidly lose its magnetization, on the opening of the circuit.

Coils, Armature —— —(See *Dynamo-Electric Machines, Armature Coils.*)

Coils, Electric —— —Convolutions of insulated wire through which an electric current may be passed. (See *Electro-Magnet.*

Coils, Henry's—— —A number of separate induction coils so connected that the currents induced in the secondary wire of the first coil are caused to induce currents in the

secondary wire of the second coil, with whose primary it is connected in series.

A series of three of Henry's coils is shown in Fig. 108. An intermittent battery current is sent into a, the secondary of which, b, is connected with the primary c, of the second coil. The secondary d, of the second coil, is connected with the primary e, of the third coil, and the currents finally induced in f, are employed for any useful purpose, such as the magnetization of a bar of iron at g.

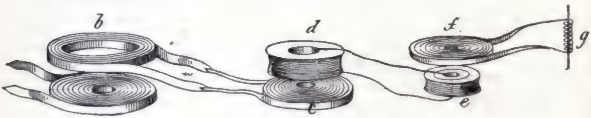


Fig. 108.

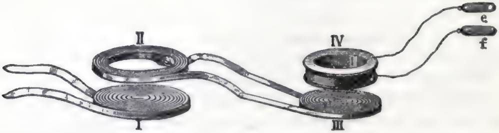


Fig. 109.

The current in b is sometimes called a *Secondary Current;* that induced by this secondary current in d is called a *Tertiary Current*, or *a Current of the Third Order;* that in f, *a Current of the Fourth Order.* Henry carried these successive inductions up to currents of the *Seventh Order.*

Henry's coils in reality consist of separate induction coils, connected, as above explained, in series.

In Fig. 109, the tertiary current induced in IV., may be employed to give shocks to a person grasping the handles, e and f.

Coils, Induction ——— —(See *Induction Coils.*)

Coils, Magnet ——— —(See *Magnet Coils.*)

Coils, Resistance ——— —Coils of wire, the electrical resistance of which is known, employed for measuring the resistance of any circuit.

In order to avoid the magnetizing effects of the coils on the needles of the galvanometers used in electric measurements, the wire of the resistance coil is doubled on itself before being wound, and its ends electrically connected with the brass bars, E, E, Fig. 110. The insertion of the plug-key cuts the coil out of the circuit by short-circuiting. (See *Box, Resistance. Balance, Wheatstone's, Electric. Standard Resistance Coil.*)

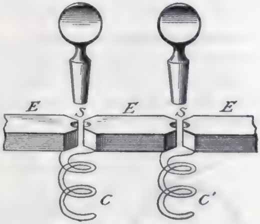


Fig. 110.

The coils are made of German silver, or platinoid, whose resistance is not much affected by heat.

Coils, Shunt ——— —Coils placed in a derived or shunt circuit. (See *Circuit, Shunt.*)

Collectors of Dynamo Electric Machines.—The metallic brushes that rest on the commutator cylinder, and carry off the current generated on the rotation of the armature. Collectors are familiarly called commutators.

Collectors, Electric.—Devices employed to collect or take off electricity from a moving electric source.

Collectors of Frictional Electric Machines.—The metallic points that collect the charge from the glass plate or cylinder of a frictional electric machine.

Column, Electric ——— —A term formerly applied to a voltaic pile. (See *Pile, Voltaic.*)

Completed Circuit.—(See *Circuit, Closed, Completed* or *Made.*)

Commercial Efficiency of Dynamo.—The useful or available electrical energy in the external circuit, divided by the total mechanical energy required to drive the dynamo that produced it. (See *Coefficient, Economic, of Dynamo.*)

Commutator.—Generally, a device for changing the direction of an electric current.

That part of a dynamo-electric machine that causes the currents that alternate or change their direction twice in every revolution of the armature, between a pair of magnet poles, to flow in one and the same direction in the external circuit.

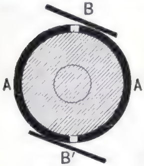


Fig. 111.

One end of an armature coil is connected with A′, Fig. 111, and the other with A. The brushes are so set that A and A′ are in contact with B′ and B, respectively, as long as the current flows in the same direction, in the armature coil connected therewith, but enter into contact with B and B′, when the current changes its direction, and continue in such contact as long as it flows in this direction. *The current will therefore flow through any circuit connected with the brushes in one and the same constant direction.*

The number of metallic pieces A and A′, in the *commutator cylinder* depends on the number, arrangement and connection of the armature coils, and on the disposition of the *magnetic field* of the machine.

For details of various commutators of this description, see *Dynamo-Electric Machines.*

The *Reverser* used by Ruhmkorff in his induction coil, for cutting off, or for reversing the direction of the *primary current* is shown in Fig. 112, and was called by him the *commutator.* (See *Ruhmkorff Coil.*)

Two metallic strips, V V, supported on a cylinder of insu-

lating material are in contact with the battery terminals P and N through two vertical springs that bear on them. On a half rotation of the cylinder by the thumb screw L, the strips V, V′, change places as regards the vertical springs, and thus reverse the direction of the battery current.

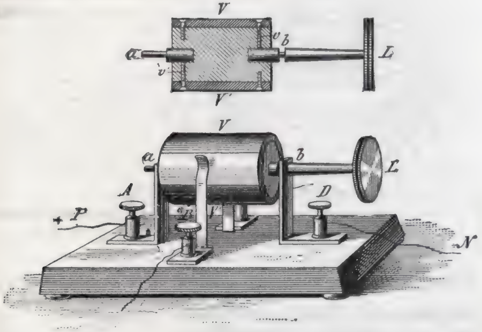


Fig. 112.

Compass, Azimuth, or Mariner's——— —A compass used by mariners for measuring the horizontal distance of the sun or stars from the magnetic meridian. (See *Azimuth, Magnetic.*)

A single magnetic needle, or several magnetic needles, are placed side by side on the lower surface of a card, called the *compass card.* This card is divided into the four *cardinal points,* N, S, E and W, and these again sub-divided in thirty-two points called *Rhumbs.*

In the azimuth compass these divisions are supplemented by a further division into degrees.

A form of azimuth compass is shown in Fig. 113. In order to maintain the compass box in a horizontal position, despite the rolling of the ship, the box, A B, is suspended in the larger box, P Q, on two concentric metallic circles, C D, and E F, pivoted on two horizontal axes at right angles to each other; or, as it is technically termed, in *Gimbals*. Sights, G H, are provided for measuring the magnetic azimuth of any object.

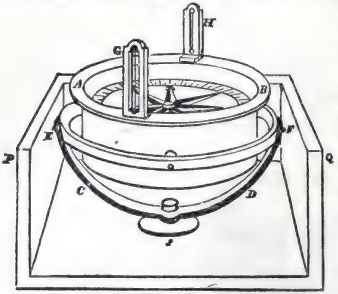


Fig. 113.

Compass Card.—(See *Compass, Azimuth.*)

Compensating Magnet.—(See *Magnet, Compensating.*)

Component, Horizontal and Vertical, of Earth's Magnetism.—That portion of the earth's directive force which acts in a horizontal direction.

Let A B, Fig. 114, represent the *direction* and *magnitude* of the earth's magnetic field on a magnetic needle. The magnetic force will lie in the plane of the magnetic meridian, which will be assumed to be the plane of the paper C A D. The earth's field, A B, can be resolved into two components, A D, the *horizontal* component, and A C, the *vertical* component.

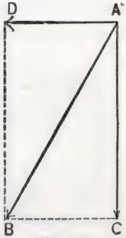


Fig. 114.

In the case of a magnetic needle, which, like the ordinary compass needle, is free to move in a horizontal plane only, the

horizontal component alone directs the needle. When the needle is free to move in a vertical plane, and the plane corresponds with that of the magnetic meridian, this entire magnetic force, A B, acts to place the needle, supposed to be properly balanced, in the direction of the lines of force of the earth's magnetic field at that point. In the vertical plane at right angles to the plane of the magnetic meridian, the vertical component alone acts, and the needle points vertically downwards.

Components.—The two or more separate forces into which any single force may be resolved; or, conversely, the separate forces which together produce any single resulting force.

When two or more forces simultaneously act to produce motion in a body, the body will move with a given force in a single direction called the *resultant.* The separate forces, or directions of motion, are called the *components.*

Two forces acting simultaneously on a body at A, Fig. 115, tending to move it in the direction of the arrows, along A B and A C, with intensities proportioned to the lengths of the lines A B and A C, respectively, will move it in the direction A D, obtained by drawing B D and D C, parallel to A C and A B, respectively, and drawing A D through the point of intersection, D. This is called the *Composition of Forces.* A D is the resultant force and A B and A C are its components.

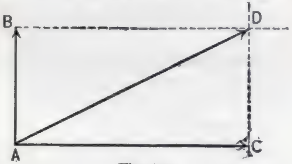


Fig. 115.

Conversely, a single force, acting in the direction of D B, Fig. 116, against a surface, B C, may be regarded as the resultant of the two separate forces, D E and D C, one parallel to C B, and one perpendicular to it. D E, being parallel to

C B, produces no pressure, and the absolute effect of the force will be represented by C D.

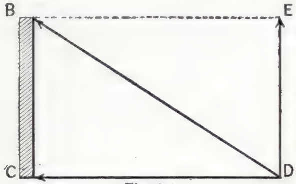


Fig. 116.

This is called the *resolution of forces*, the force, D B, being resolved into the components D E and D C.

That component of the earth's magnetic force which acts in a horizontal, or in a vertical direction respectively.

Compound, Binary —— Compound, Chatterton's.—A compound for cementing together the alternate coatings of gutta-percha employed on a cable conductor, or for filling up the spaces between the strand conductors. (See *Binary Compound.*)

The composition is as follows:

Stockholm tar	1	part by weight.
Resin	1	"
Gutta-percha	3	"

(*Clark & Sabine.*)

Compound, Clark's.—A compound for the outer casing of the sheath of submarine cables.

Its composition is as follows:

Mineral pitch	65	parts by weight.
Silica	30	"
Tar	5	"

(*Clark & Sabine.*)

Compound Magnet.—(See *Magnet, Compound.*)

Compound Winding of Dynamo-Electric Machines.—A method of winding in which shunt and series coils are placed on the field magnets. (See *Dynamo-Electric Machines.*)

Concentric Carbon Electrodes.—(See *Carbons, Cored.*)

Condenser, or Accumulator.—A device for increasing the capacity of an insulated conductor by bringing it near another insulated earth-connected conductor, but separated from it by a medium that will readily permit induction to take place through its mass.

If the conductor A, Fig. 117, standing alone and separated from other conductors, be connected with an electric machine, it will receive only a very small charge.

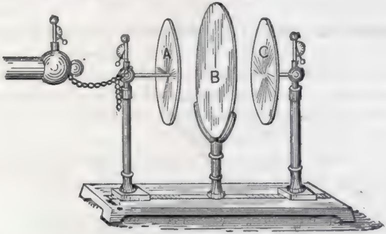


Fig. 117.

If, however, it be placed near C, but separated from it by a *dielectric*, such as a plate of glass B, and C be connected with the ground, A will receive a much greater charge. (See *Dielectric.*)

Suppose, for example, that A be connected with the positive conductor of a frictional electric machine; it will by *induction* produce a negative charge to the surface of C, nearest it, and repel a positive charge to the earth. The presence of these two opposite charges on the opposed surfaces of A and C produces a neutralization that permits A to receive a fresh charge from the machine. (See *Induction, Electrostatic.*)

The charge in a condenser in reality resides on the opposite

surfaces of the glass, or other dielectric separating the metallic coatings, as can be shown by removing the coatings after charging.

The condenser resulted from the discovery of the Leyden jar. (See *Jar, Leyden.*)

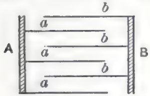


Fig. 118.

The capacity of a condenser is measured in *microfarads* (See *Farad.*)

In practice condensers are made of sheets of tin foil, *a*, *a*, *a*, *b*, *b*, *b*, connected at A and B, respectively, and separated from one another by sheets of oiled silk, or thin plates of mica.

Conducting Power, Order of.—The ability of a given length and area of cross section of a substance to conduct electricity, as compared with an equal length and area of cross section of some other substance, such as pure silver or copper.

No substance is known that does not offer some *resistance* to the passage of an electric current.

The following table is taken from Sylvanus P. Thompson's "Elementary Lessons in Electricity and Magnetism :"

Silver	Good conductors.
Copper	
Other metals	
Charcoal	
Water	Partial conductors.
The human body	
Cotton	
Dry wood	
Marble	
Paper	
Oils	Non-conductors.
Porcelain	
Wood	
Silk	
Resins	
Gutta-percha	
Shellac	
Ebonite	
Paraffin	
Glass	
Dry air	

Conductive Discharge.—(See *Discharge, Conductive.*)

Conductor, Anisotropic —— —(See *Anisotropic Conductor.*)

Conductor, Anti-Induction—— —(See *Anti-Induction Conductor.*

Conductor, Conjugate ——— —"In a system of linear conductors, any pair of conductors are said to be conjugate to one another when a variation of the resistance or the E. M. F. in the one causes no variation in the current of the other." (*Brough.*)

Conductors, Isotropic—— —(See *Isotropic Conductor.*)

Conductors.—Substances which will permit the passage of an electric current through them.

This term is opposed to *non-conductors,* or those which will not permit the passage of an electric current through them.

Conduit, Electric, Underground—— —A space or place for the reception of electric wires or cables. (See *Subway, Electric.*)

Conservation of Energy.—The indestructibility of energy.

The total quantity of energy in the universe is unalterable.

The total energy of the universe is not, however, available for the production of useful work for man.

When energy disappears in one form it reappears in some other form. This is called the *correlation* or *conservation* of *energy.* The commonest form in which energy reappears is as *heat,* and in this case some of the heat is lost to the earth by radiation. This *degradation,* or *dissipation of energy* causes some of the energy of the earth to become *non-available* to man.

Energy is therefore *available* and *non-available.* (See *Entropy.*)

Consequent Magnet Poles.—The name given to the magnetic poles formed by two free N. poles or two free S. poles placed together. (See *Anomalous Magnets.*)

Contact Electricity.—Electricity produced by the mere contact of dissimilar metals.

The mere contact of two dissimilar metals results in the production of opposite electrical charges on their opposed surfaces, or in a difference of electric potential between these surfaces. The mere contact of dissimilar metals cannot produce a constant electric current. An electric current possesses kinetic energy. To produce a constant electric current, therefore, energy must be expended. In the voltaic pile though the contact of dissimilar metals produces a difference of potential, yet the cause of the current is to be found in chemical action. (See *Cell, Voltaic.*)

Contact-Series.—A series of metals arranged in such an order that each becomes positively electrified by contact with the one that follows it.

The contact values of some metals, according to Ayrton and Perry, are as follows :

CONTACT-SERIES.

Difference of Potential in Volts.

Zinc Lead	.210
Lead Tin	.069
Tin Iron	.313
Iron Copper	.146
Copper Platinum	.238
Platinum Carbon	.113

The difference of potential between zinc and carbon is equal to 1.089, and is obtained by adding the successive differences between them.

This fact is known technically as *Volta's Law*, which may be formulated as follows:

The difference of potential produced by the contact of any two metals is equal to the sum of the differences of potentials between the intervening metals in the contact series.

Contact Theory of Voltaic Cell.—(See *Cell, Voltaic.*)

Contacts.—A variety of faults occasioned by the accidental contact of a circuit with any conducting body.

Contacts of this character are of the following varieties, viz.:

(1) *Full*, or *Metallic*, as when the circuit is accidentally placed in firm connection with another metallic circuit.

(2) *Partial*, as by imperfect conductors being placed across wires, or bad earths, or defective insulation.

(3) *Intermittent*, as by occasional contacts of swinging wires, etc.

Contractures.—In electro-therapeutics, a prolonged muscular spasm, or tetanus, caused by the passage of an electric current.

Controlling Clocks, Electric—— —In a system of time telegraphy, the master clock, whose impulses move or regulate the secondary clocks. (See *Clocks, Electric.*)

Controlled Clocks, Electrically—— —In a system of time telegraphy, the secondary clocks, that are either driven or controlled by the master clock. (See *Clocks, Electric.*)

Convection, Electric——; Convection Streams.—The air particles, or air streams, that are thrown off from the pointed ends of a charged, insulated conductor.

Convection streams, like currents flowing through conductors, act magnetically, and are acted on themselves by mag-

nets. The same thing is true of the brush discharge of the voltaic arc, and of convective discharges in vacuum tubes.

Convection, Electrolytic——.—A term proposed by Helmholtz to explain the apparent conduction of electricity by an electrolyte, without consequent decomposition.

Helmholtz assumes that molecules of oxygen or hydrogen, adhering to the electrodes during electrolysis, are mechanically dislodged and diffused through the liquid, thus carrying off the electricity by the charges received by them while in contact with the electrodes.

Convection of Heat, Electric——.—A distribution of heat during the passage of a current through an unequally heated conductor.

If the central portions of a metallic bar are heated, the curve of heat distribution is symmetrical. On sending an electric current through the wire it is heated according to Joule's law, and the curve of heat distribution is still symmetrical. But the current in passing from the colder to the hotter parts of the wire produces an additional heating effect at this point, and in passing from the warmer to the colder parts of the wire, produces a cooling effect. (See *Effect, Peltier. Effect, Thomson.*) The curve of heat distribution is then no longer symmetrical. The term the *Electrical Convection of Heat* has been given to the dissymmetrical distribution of heat so effected.

Sir Wm. Thomson, who studied these effects, found that the electrical convection of heat in copper takes place in the opposite direction to that in iron; that is to say, the electrical convection of heat is negative in iron, (*i. e.*, the direction is opposite to that of the current) and positive in copper.

Convective Discharge.—(See *Discharge, Convective.*)

Converter, or Transformer.—The inverted induction coil employed in systems of distribution by means of alternating currents.

A *converter*, or *transformer*, consists essentially of an induction coil in which the primary wire, P P, Fig. 119, is long and thin, and consequently of high electric resistance as compared with the secondary wire, S S, which is short, thick, and of low resistance.

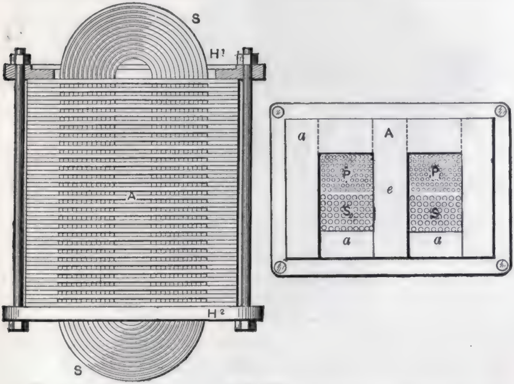


Fig. 119.

To prevent heating and loss of energy in conversion, the core is thoroughly laminated. To lower the magnetic resistance, the converter is iron-clad.

In a system of electrical distribution by means of transformers, alternating currents, of small volume and comparatively considerable difference of potential, are sent over a line from a distant station, and passing into the primary wire of a number of converters, generally connected to the line *in multiple-arc* produce, by induction, currents of comparatively large volume and small difference of potential in the secondary wires. Various electro-receptive devices are connected in multiple-arc with the secondary wires.

This method of distribution greatly reduces the cost of the main conducting wires or leads in certain cases, since considerable energy may be conveniently sent over a comparatively thin wire, if the difference of potential is sufficiently great.

The general arrangement of the converters on the main

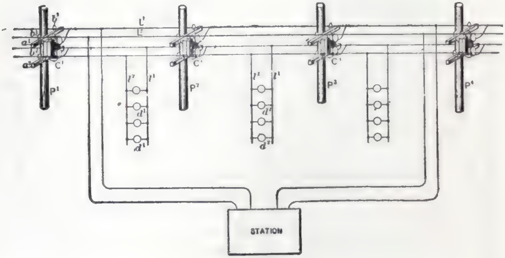


Fig. 120.

line, and the connection of the secondary circuits with the electro-receptive device in such a system, is shown in Fig. 120. The converters are supported on the line poles, as more clearly shown in Fig. 121, in which the terminals of the primary and secondary of the converter are readily seen.

When the converter is properly constructed the loss of conversion is but small at full load; that is to say, the watts in the secondary are very nearly equal to those in the primary. A current of 10 ampères, at 2000 volts, when passed into a converter, the number of whose turns in the primary is twenty times the number in its secondary, will produce in its secondary, a current of 200 ampères at about 100 volts. Here, the number of watts in the two cases is exactly the same, or theoretically 20,000 watts. In reality, it is somewhat

smaller. In general, the shorter the wire on the secondary, and the smaller its number of turns, the greater is the reduction in the difference of potential, and the greater is the current produced.

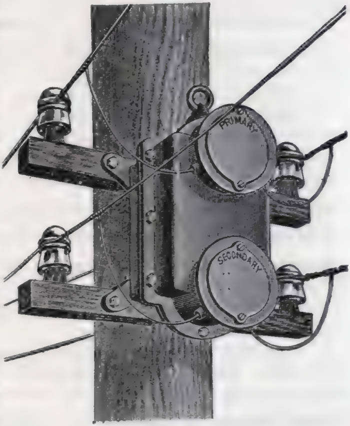


Fig. 121.

Co-Ordinates, Axes of ——— —The axes of abscissas and ordinates.

The two straight lines, perpendicular to each other, to which distances representing values are referred for the graphic representation of such values. (See *Abscissas, Axis of.*)

Copper Bath.—(See *Baths, Copper, etc.*)

Cords, Electric ——— —Flexible, insulated electric conductors, generally containing at least two parallel wires.

They are named from the purposes for which they are employed, *battery cords, dental cords, lamp cords, motor cords, switch cords, etc.*

Core of Cable.—The conducting wires of an electric cable. (See *Cable, Electric.*)

Core Ratio of Cable.—The ratio between the diameter of the insulator of a cable and the mean diameter of the strand.

The core ratio is represented by $\frac{D}{d}$; where D, is the diameter of the insulator, and d, the mean diameter of the strand. Should the extreme diameter of the strand of a cable be used in calculations for insulation resistance, inductive capacity, etc., erroneous values would be obtained. The measured diameter of the copper conductor is consequently decreased some five per cent. by means of which the correct values are approximately given. (Clark & Sabine.)

Cored Carbons.—(See *Carbons, Cored.*)

Cores, Armature—— —(See *Armature Cores.*)

Cores, Armature, Ventilation of —— —Means for the passage of fluids, such as air through the armature cores of dynamo-electric machines so as to prevent the undue accumulation of heat.

A properly proportioned dynamo-armature should need no ventilation, since in such the amount of heat generated is small as compared with the extent of the radiating surface.

Cores, Lamination of—— —Structural subdivisions of the cores of magnets, armatures, and pole pieces of dynamo-electric machines, electric motors, or similar apparatus, in order to prevent heating and subsequent loss of energy from the production of *local, eddy* or *Foucault currents.*

These laminations are obtained by forming the cores of sheets, rods, plates, or wires of iron insulated from one another.

The cores of armatures should be divided in planes at right angles to the armature coils ; or in planes parallel to the direction of the lines of force and to the motion of the armature ; or in general, in planes perpendicular to the currents that would otherwise be generated in them.

Pole pieces should be divided in planes perpendicular to the direction of the currents in the armature wires.

Magnet cores should be divided in planes at right angles to the magnetizing current.

Cosine.—One of the trigonometrical functions. (See *Trigonometry.*)

Cotangent.—One of the trigonometrical functions. (See *Trigonometry.*)

Coulomb.—The unit of electrical quantity.

A definite quantity or amount of the *thing or effect* called electricity.

Such a quantity of electricity as would pass in one second in a circuit whose *resistance* is one *ohm,* under an *electro-motive force* of one *volt.*

The quantity of electricity containea in a condenser of one *farad* capacity, when subjected to an electro-motive force of one *volt.*

Coulomb-Volt.—A Joule, or .7373 foot pound.

The term is generally written *volt-coulomb.* (See *Volt-Coulomb.*)

Counter-Electro-Motive Force.—An opposed or *reverse electro-motive force* produced in an electric source, which tends to produce a current in the opposite direction to that regularly produced by the source.

In an electric motor, an electro-motive force contrary to that produced by the current which drives the motor, and which is proportional to the velocity attained by the motor.

Counter-electro-motive force acts to diminish the current in the same manner as a resistance would, and is therefore sometimes called the *spurious resistance* in order to distinguish it form the *ohmic* or *true resistance.*

Counter-electro-motive force is sometimes expressed in ohms, though it is not *true ohmic resistance.* (See *Spurious Resistance.*)

The counter-electro-motive force of a voltaic battery is due to the *polarization* of the cells. Since this force is due to the

current in the cell, it can never exceed such current or reverse its direction. It may, however, equal it and thus stop its flow. (See *Polarization of Voltaic Cell.*)

In a *storage cell,* the charging current produces an electro-motive force counter to itself, which, as in a motor, is a true measure of the energy stored in the cell. Economy requires that the electro-motive force of the charging current should be as little greater as possible than that of the counter-electro-motive force of the cell it is charging.

In a voltaic arc a counter-electro-motive force is set up by polarization.

Counters, Electric —— —Various devices for counting and registering such quantities as the number of fares collected, gallons of water pumped, sheets of paper printed, revolutions of an engine per second, votes polled, etc.

Various electric devices are employed for this purpose. They are, generally, electro-magnetic in character.

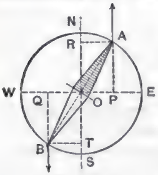


Fig. 122.

Couple.—In mechanics, two equal parallel forces acting in opposite directions and tending to cause rotation.

The *moment,* or *effective power of a couple,* is equal to the intensity of one of the forces multiplied by the perpendicular distance between the directions of the two forces.

Couple, Magnetic —— —The couple which tends to turn a magnetic needle, placed in the earth's field, into the plane of the magnetic meridian.

If a magnetic needle is in any other position than in the magnetic meridian, there will be two parallel and equal forces acting at A and B, Fig. 122, in the directions shown by the arrows. Their effect will be to rotate the needle until it comes to rest in the magnetic meridian N S.

The total force acting on either pole of a needle free to move in any direction is equal to the strength of that pole

multiplied by the total intensity of the earth's field at that place, or, if free to move in a horizontal direction only, is equal to the intensity of the earth's horizontal component of magnetism at the place at which the needle is situated, multiplied by the strength of that pole.

The effective power or moment of the magnetic couple is equal to the force exerted on one of the poles multiplied by the perpendicular distance, P Q, between their directions.

Couple, Thermo-Electric ——— —Any two dissimilar metals which, when connected at their ends only, will produce an electric current when one set of ends is heated more than the other.

Couple, Voltaic ——— —The two plates of dissimilar metals, or other substances in a voltaic battery which are immersed in the liquid of the cell, as for example, the zinc and copper plates of the simple voltaic cell.

All voltaic cells have two metals, or a metal and a metalloid, or two gaseous or liquid substances which are of such a character that, when dipped into the battery solution, one only is chemically acted on.

Each of these substances is called an *element* of the cell, and the two taken collectively form a *voltaic couple.*

The elements of a voltaic couple may consist of two gases or two liquids. (See *Gas Battery.*)

Coupling of Voltaic Cells or Other Electric Sources.—A term indicating the manner in which a number of separate electric sources are connected so as to form a single source. (See *Circuits, Varieties of.*)

C. P.—A contraction frequently used for candle power. (See *Candle, Standard.*)

Crater in Positive Carbon.—The depression at the end of the positive carbon which appears when a voltaic arc is formed. (See *Arc, Voltaic.*)

Creosoting.—A process employed for the preservation of wooden telegraph poles by injecting creosote into the pores of the wood. (See *Pole, Telegraphic.*)

Creeping.—The formation of salts by efflorescence on the sides of the porous cup of a voltaic cell, on the walls of the vessel containing the electrolyte, or on the walls of any vessel containing a saline solution.

Paraffining the portions of the walls out of the liquid, or covering the surface of the liquid with a neutral oil, obviates much of this difficulty. (See *Efflorescence.*)

Crith.—A term proposed by A. W. Hoffman, as a unit of volume, or the volume of one litre, or cubic decimetre, of hydrogen at 0° C. and 760 mm. barometric pressure.

Critical Current.—The current at which a certain result is reached.

Critical Current of a Dynamo.—That value of the current at which the *characteristic curve* begins to depart from a nearly straight line. (*Sylvanus P. Thompson.*)

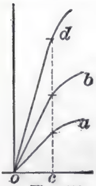


Fig. 123.

As a rule the critical current of a dynamo occurs when the speed is such that the electromotive force is nearly two-thirds the maximum value.

In Fig. 123 the critical current is shown in three different cases, as occuring where the dotted vertical line cuts the characteristic curves.

The speed at which a series dynamo excites itself is often called the *critical speed.*

Cross, Electric ——— —A connection, generally metallic, accidentally established between two conducting lines.

A defect in a telegraph or telephone circuit caused by two wires coming into contact by crossing one another.

A swinging or intermittent cross is caused by wires which are too slack, being occasionally blown into contact by the wind.

A weather cross arises from defective action of the insulators in wet weather.

Crossing Wires.—A device employed in telegraphic circuits whereby a faulty conductor of a telegraph line is cut out of the circuit by *crossing* over to a neighboring, less used, line.

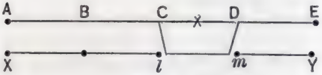


Fig. 124.

To cut out a faulty section of wire in any circuit, such as C D, in the circuit A B C D E, Fig. 124, a cross connection is made to a line X Y, running near it, and which may be temporarily thrown out of use. By this means the interruption of an important circuit may be avoided.

Crucible, Electric—— —A crucible in which the heat of the voltaic arc, or of electric incandescence, is employed either to perform difficult fusions, or for the purpose of effecting the reduction of metals from their ores, or the formation of alloys. (See *Furnace, Electric.*)

Crystal.—A solid body bounded by symmetrically disposed plane surfaces.

A definite form or shape is as characteristic of an organic substance, as it is of the animal or plant. Each substance has a form in which it generally occurs. There are, however, certain modifications of the typical form which cause plane surfaces to appear curved, and the symmetrical arrangement of the faces to disappear. These modifications often render it extremely difficult to recognize the true typical form.

For the different fundamental crystalline forms, or systems of crystals, see any standard work on chemistry.

Crystallization.—Solidification from a state of solution or fusion, with the assumption of definite crystalline forms.

The crystallization of a dissolved solid is favored by any cause that gives increased freedom of movement to the par-

ticles of the solid, such for example as, *solution, fusion, sublimation*, or *precipitation.*

Crystallization by Electrical Decomposition.—The crystalline deposition of various metals by the passage of an electric current through solutions of their salts under certain conditions.

A strip of zinc immersed in a solution of sugar of lead, (acetate of lead) soon becomes covered with bright metallic plates of lead, that are electrically deposited by the weak currents due to minute *voltaic couples* (See *Couple, Voltaic*), formed with the zinc by particles of iron, carbon, or other impurities in the zinc. The deposit assumes at times a tree-like growth, and is therefore called a *lead tree.*

Cube, Faraday's—— —(See *Net, Faraday's.*)

Current, Alternating or Reversed—— —A current which flows alternately in opposite directions.

A current whose direction is rapidly *reversed.*

The non-commuted current generated by the differences of potential in the armature of a dynamo-electric machine is an alternating current.

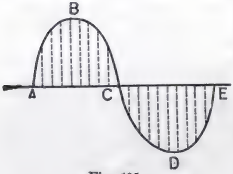


Fig. 125.

In a *characteristic curve* of the electro-motive forces of alternating currents, positive electro-motive forces, or those that would produce currents in a certain direction, are indicated by values *above* a horizontal line, and negative electro-motive forces, by values *below* the line.

The curves A B C and C D E, Fig. 125, are often called *phases*, and represent the alternate phases of the current.

Current, Alternative —— **—or Voltaic Alternatives.**—A term sometimes used in electro-therapeutics for *a sudden alternating current.* (See *Alternatives, Voltaic.*)

Current, Commuted —— —The current of any electric source which produces alternating currents, that have been caused to flow in one and the same direction by the aid of a *commutator*. (See *Commutator.*)

Current, Continuous —— —An electric current which flows in one and the same direction.

This term is used in the opposite sense to alternating current.

Current, Critical —— —(See *Critical Current.*)

Current Density —— —The quantity of current which passes in any part of a circuit as compared with the area of cross section of that part of the circuit.

In a dynamo-electric machine the current density in the armature wire should not, according to Sylvanus P. Thompson, exceed 2,500 ampères per square inch of area of transverse section of conductor.

In electro-plating, for every definite current strength that passes through the bath, a definite weight of metal is deposited, the character of which depends on the current density. The character of an electrolytic deposit will therefore depend on the *current density* at that part of the circuit where the deposit occurs.

Current, Diacritical —— —(See *Diacritical Current.*)

Current, Direct —— —A current constant in direction, as distinguished from an alternating current.

Current, Electric —— —The quantity of electricity which passes per second through any conductor or circuit, or the rate at which a definite quantity of electricity passes or flows through a conductor or circuit.

An electric current represents the ratio existing between the *electro-motive force*, causing the current, and the *resistance* which may be regarded as opposing it. This ratio is then expressed in terms of quantity of electricity per second.

The *unit of current* or the *ampère* is equal to *one coulomb per second.* (See *Ampère. Coulomb.*)

The word current must not be confounded with the mere act of flowing; electric current signifies rate of flow, and always supposes an electro-motive force to produce the current and a resistance to oppose it.

The electric current is assumed to flow out from the positive terminal or of a *source,* through the circuit and back into the source at the *negative terminal,* and is assumed to flow into the positive terminal of an electro-receptive device such as a lamp, motor, or storage battery, and out of its negative terminal; or, in other words, the positive pole of the source is always connected to the positive terminal of the electro-receptive device.

Current, Element of ——.—A term employed in mathematical discussions, to indicate a very small part of a current in considering its action on a magnetic needle or other similar body.

Current, Faradic ——.—(See *Faradic Current.*)

Current Induction.—(See *Voltaic Induction. Electro-Dynamics.*)

Current, Intensity of.—(See *Intensity of Current.*)

Current Meter.—(See *Galvanometer.*)

Current, Reversed ——.—A current whose direction is changed at intervals. (See *Current, Alternating.*)

Current Reverser.—A switch, or other apparatus, to reverse the direction of a current.

Currents, Ampèrian ——.—(See *Ampèrian Currents. Magnetism, Ampère's Theory of.*)

Currents, Diaphragm ——.—(See *Diaphragm Currents.*)

Currents, Earth ——.—(See *Earth Currents.*)

Currents, Eddy, Local, Foucault, or Parasitical ———————Useless currents produced in the metallic masses of the pole pieces, armatures, or field magnet cores of dynamo-electric machines or motors, either by the motion of these parts through magnetic fields, or by the variations in the strength of electric currents flowing near them.

Eddy currents may even be produced in the mass of the conducting wire on the armature, when this is comparatively heavy.

These currents are called *eddy currents, local currents, Foucault currents,* or *parasitical* currents. They form closed circuits of comparatively low resistance, and tend to cause undue heating of armatures or pole pieces. They not only cause a useless expenditure of energy, but interfere with the proper operation of the device.

To reduce them as much as practicable, the pole pieces and armature cores are laminated. (See *Cores, Lamination of.*)

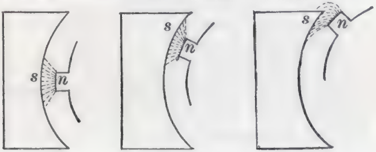


Fig. 126.

Since eddy currents in dynamo-electric machines are due to variations in the magnetic strength of the field magnets, or of the armature, they will be of greatest intensity when the changes in the magnetic strength are the greatest and most sudden.

These changes are most marked, and consequently the eddy currents are particularly strong, at those corners of the pole pieces of a dynamo from which the armature is moved in its rotation, as will be seen from an inspection of Fig. 126.

Fig. 127, shows eddy currents generated in pole pieces.

Currents, Extra.—In a coil of wire through which a current is passing, the current produced by the inductive action of the current on itself at the moment of breaking or making the circuit.

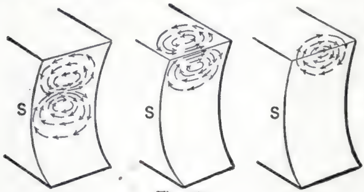


Fig. 127.

The extra current induced on breaking flows in the same direction as the original current and acts to strengthen and prolong it.

The extra current induced on making or completing a circuit, is in the *opposite direction*, tending to *oppose* or *retard* the current.

Both of these currents are called *induced* or *extra currents.* The former is called the *direct-induced-current*, and the latter the *reversed-induced-current.*

In order to distinguish this induction from that produced in a *neighboring conductor* by the passage of the electric current, it is called *self-induction.*

The effect of the self-induced or extra currents on telegraphic line is to influence the speed of signaling by retarding the beginning of a signal, and prolonging its termination.

The greater the number of turns of wire in a circuit, or magnet, and the greater the mass of iron in its core, the greater the strength of the extra current.

Currents, Natural———A term sometimes applied to earth currents. (See *Earth Currents.*)

Currents, Negative and Positive—— —A term employed in telegraphy for currents sent over a line in a positive or a negative direction, respectively. (See *Telegraph, Single-Needle.*)

Currents, Orders of —— —Induced electric currents named from the order in which they are induced, as currents of the first, second, third, fourth, etc., orders.

An induced current can be caused to induce another current in a neighboring circuit, and this a third current, and so on. Such currents are distinguished by the term, currents of the *second, third, fourth, etc., order*. (See *Coils, Henry's.*)

Currents, Rectilinear —— —Currents flowing through straight or rectilinear portions of a circuit.

In studying the effects of attraction or repulsion produced by electric currents, the peculiarity of shape of any part of the circuit is often applied to the current flowing through that circuit.

Currents, Sinuous—— —A term sometimes applied to currents flowing through a sinuous conductor.

Sinuous currents exert the same effects of attraction or repulsion on magnets, or on other circuits, as would a rectilinear current whose length is that of the axis of such current.

This can be shown by approaching the circuit A′B′, Fig. 128, consisting of the sinuous conductor A′, and rectilinear conductor B′, to the movable conductor ABC on which it produces no effect. The current A′, therefore, neutralizes the effects of the current B′; or, it is equal to it in effect.

In calculating the effects of sinuous currents, it is convenient to consider them as consisting of a succession of short, straight portions at right angles to one another, as shown in Fig. 129.

Currents, Undulatory—— —Currents the strength and direction of flow of which gradually change.

The currents produced by all alternate current dynamos are not of the character generally known as *pulsatory*, in which the strength and direction change suddenly. In actual practice, such currents differ from undulatory currents more in degree than in kind, since, when sent into a line, the effects

of *retardation* tend to obliterate, to a greater or less extent, the marked differences in intensity on which their undulatory character depends.

The currents produced in the coils of the Siemens' magneto-electric key, in which the mechanical to-and-fro motion of the key sends electrical impulses into the line, are, in point of fact, undulatory in character when they follow one another rapidly.

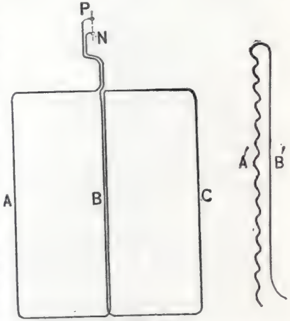


Fig. 128.

The currents in most dynamo-electric machines, the number of whose armature coils is comparatively great, are, so far as the variations in their intensity or strength are concerned, undulatory in character even when non-commuted.

The currents on all telephone lines that transmit articulate speech are undulatory. This is true, whether the transmitter employed merely varies the resistance by variations of pressure, or actually employs makes-and-breaks that rapidly follow one another.

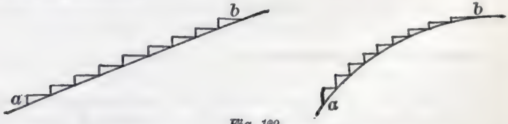


Fig. 129.

Curve, Ballistic———(See *Ballistic Curve.*)

Curves, Characteristic ———(See *Characteristic Curves.*)

Cut-Out, Automatic—— for Multiple Connected Electric Lamps.—A device for automatically cutting a lamp out of the circuit of the leads.

Automatic cut-outs for incandescent lamps when connected to the leads in multiple-arc, consist of strips of readily melted metal called *safety fuses*, which on the passage of an abnormal current fuse and thus automatically break the circuit in that particular branch. (See *Safety Catch.*)

Cut-Out, Automatic —— for Series Connected Lamps.—A device whereby an electric arc lamp is, to all intents and purposes, automatically cut out,or removed from the circuit, by means of a *shunt* of low resistance, which permits the greater part of the current to flow past the lamp.

It will be observed that the lamp is still in the circuit, but is to all practical intents cut out from the same, since the proportion of the current that now passes through it is too small to operate it.

In most series arc lamps the automatic cut-out is operated by means of an electro-magnet placed in a shunt circuit of high resistance around the carbons.

If the carbons fail to properly feed, the arc increases in length and consequently in resistance. More current passes through the shunt magnet, until finally, when a certain predetermined limit is reached, the armature of the electro-magnet is attracted to the magnet pole and mechanically completes the short circuit past the lamp.

In some automatic cut-outs the fusion of a readily fused wire, placed in a shunt circuit around the carbons, permits a spring to complete the short circuit.

The automatic cut-out prevents the accidental extinguishing of any single lamp in a series circuit from extinguishing the entire circuit.

Cylindrical Carbon Electrodes. — (See *Carbons, Cored.*)

Cymogene.—An extremely volatile liquid which is given off from crude coal-oil during the early parts of its distillation.

The two liquids which are obtained from the condensation of the vapors given off during the first parts of the distillation of crude coal oil are called *cymogene*, and *rhigolene.* These liquids are employed on account of their extreme volatility for the artificial production of cold.

Rhigolene is employed by some for the *treatment* or *flashing* of the carbons used in incandescent lamps. (See *Flashing, Method of.*)

Damping.—The act of bringing a swinging magnetic needle quickly to rest, so as to determine its amount of deflection, without waiting until it comes to rest after repeated swingings to and fro.

Damping devices are such as offer resistance to quick motion, or high velocities. Those generally employed in electrical apparatus are either *air* or *fluid friction*, obtained by placing vanes on the axis of rotation, or by checking the movements of the needle by means of the currents it sets up, during its motion, in the mass of any conducting metal placed near it. These currents, as Lenz has shown, always tend to produce motion in a direction opposed to that of the motion causing them. *Bell-shaped magnets* are especially suitable for this kind of damping. (See *Magnet, Bell-Shaped.*)

The needle of a galvanometer is *dead-beat*, when its *moment of inertia* is so small that its oscillations in an intense field are very quick, and die out very rapidly, and the needle therefore moves sharply over the scale from point to point and comes quickly to a *dead stop.*

Daniell's Voltaic Cell.—(See *Cell, Voltaic.*)

Dash-Pot.—A mechanical device to prevent too sudden motion in a movable part of any apparatus.

The dash-pot of an automatic regulator, or of an arc-lamp, is provided to avoid too sudden movements of the collecting brushes on the commutator cylinder, or the too sudden fall of

the upper carbon. Such devices consist essentially of a loose fitting piston that moves through air or glycerine.

Dash-pots are species of damping devices, and, like the damping arrangements on galvanometers or magnetic needles, prevent a too free movement of the parts with which they are connected. (See *Damping.*)

Dead-Beat Galvanometer. — (See *Galvanometer, Dead Beat.*)

Dead Earth.—(See *Earths.*)

Dead Turns of Armature Wire, or Dead Wire. —That part of the wire on the *armature* of a dynamo-electric machine which produces no useful electro-motive force, or resultant current, on movement of the armature through the magnetic field of the machine.

The wire on the inside of a Gramme or ring armature, is *dead-wire.*

Dead-Wires.—Disused and abandoned electric wires.

The term *dead* is often applied to a wire through which no current is passing. The term, however, is more properly applied to a wire formerly employed, but subsequently abandoned.

Dead wires in the neighborhood of active wires are a constant menace to life and property, and should invariably be carefully removed.

It is often a matter of considerable importance to be able to determine whether or not a current is passing through a wire. When the wire is not inclosed in a moulding, or fastened against a wall, this can readily be ascertained by bringing a small compass needle near the wire, when it will tend to set itself across the wire.

The term dead wire, as will be seen, is used in two distinct senses.

Death, Electrical ——— —Death resulting from the the passage of the electric current through the human body.

The exact manner in which an electric current causes death is not known. When the current is sufficiently powerful, as in a lightning flash, or a powerful dynamo current, insensibility is practically instantaneous.

Death may be occasioned—

(1) As the direct result of physiological shock.

(2) From the action of the current on the respiratory centres.

(3) From the actual inability of the nerves or muscles, or both, to perform their functions.

(4) From an actual electrolytic decomposition of the blood or other tissues of the body.

(5) From the polarization of those parts of the body through which the current passes.

(6) From an actual rupture of parts by a disruptive discharge.

The current required to cause death will depend on a variety of circumstances, among which are :

(1) The particular path the current takes through the body, with reference to the vital organs that may lie in this path.

(2) The freedom or absence of sudden variations of electromotive force.

(3) The time the current continues to pass through the body.

In most fatal cases, it is probably the *extra-current*, or the *induced direct current on breaking*, that causes death, since, as is well known, its electro-motive force may be many times greater than that of the original current.

A comparatively low potential continuous current, cannot, therefore, be properly regarded as entirely harmless, simply because its electro-motive force is comparatively small.

Deci (as a prefix).—The one-tenth.

Deci-Lux.—The one-tenth of a lux. (See *Lux.*)

Declination, or Variation of Magnetic Needle.—The deviation of the magnetic needle from the true geographical north.

This is often called the *variation* of the magnetic needle.

The declination of the magnetic needle is either E. or W. (See *Angle of Declination.*)

The declination, or variation, is different for different parts of the earth's surface.

Lines connecting places which have the same value and direction for the declination are called *isogonal lines.* A chart on which the isogonal lines are marked is called a *variation chart.* (See *Variation Chart.*)

The value of the declination varies at different times. These variations of the declination are:

(1) *Secular,* or those occurring during great intervals of time. Thus in 1580, the magnetic needle in London, had a variation of about 11° East. This eastern declination decreased in 1622, to 6° E., and in 1680, the needle pointed to the true north. In 1692, the declination was 6° W.; in 1730, 13° W.; in 1765, 20° W.; and in 1818, the needle reached its greatest western declination and is now moving eastwards. The declination, however, is still west.

(2) *Annual,* the needle varying slightly in its declination during different seasons of the year.

(3) *Diurnal,* the needle varying slightly in its declination during different hours of the day.

(4) *Irregular,* or those which occur during the prevalence of a magnetic storm.

It has been discovered that the occurrence of a magnetic storm is simultaneous with the occurrence of an unusual number of *sun spots.* (See *Sun Spots.*)

Declinometer.—A magnetic needle suitably arranged for the measurement of the value of the magnetic declination or variation, of any place.

Decomposition.—In chemistry, the separation of a *molecule* into its constituent *atoms* or groups of atoms. (See *Molecule. Atom.*)

Decomposition, Electric or Electrolytic ——The separation of a molecule into its constituent atoms

or groups of atoms by the action of the electric current. These atoms or groups of atoms are either electro-positive or electro-negative in character. (See *Electrolysis. Anion. Kathion.*)

Deflagration of Metals, Electrical ————— — The heating of metallic substances by the electric current to a temperature at which they rapidly fuse and volatilize.

Deflagrator, Hare's ———— —The name given to a voltaic battery, of small internal resistance, employed by Hare in the deflagration of metals by the electric current.

Deflection of Magnetic Needle.—The movement of a needle out of a position of rest in the earth's magnetic field, or in the field of another magnet, by the action of an electric current, or another magnet.

Deflection Method.—A method employed in electrical measurements, as distinguished from the zero method, in which a deflection produced on any instrument by a given current, or by a given charge, is utilized for determining the value of that current or charge.

The conditions remaining the same, the same current or charge will produce the same deflection at any time. Different deflections produced by currents or charges, the values of which are unknown, are determined by certain ratios existing between the deflections and the currents or charges. These ratios are determined experimentally by the *calibration* of the instrument. (See *Calibration.*)

Deflection methods are opposed to *zero* or *null methods*, in which latter a balance of opposite electro-motive forces, or a proportionally equal fall of electric potential, is ascertained by the failure of a needle to be moved by a current or a charge.

Degradation of Energy.—Such a dissipation of energy as to render it non-available to man. (See *Conservation of Energy. Entropy.*)

Deka (as a prefix).—Ten times.

Demagnetization.—A process generally directly opposite to that for producing a magnet, by means of which the magnet may be deprived of its magnetism.

A magnet may be deprived of its magnetism, or be demagnetized—

(1) By heating it to redness.

(2) By touching to its poles magnet poles of the same name as its own.

(3) By reversing the directions of the motions by which its magetism was originally imparted, if magnetized by touch.

(4) By exposing it in a helix to the influence of currents which will impart magnetism opposite to that which it originally possessed.

Demagnetization of Watches.—(See *Watches, Demagnetization of.*)

Density of Charge.—(See *Charge, Density of.*)

Density of Current.—(See *Current, Density of.*)

Density, Magnetic ——— —(See *Magnetic Density.*)

Dental Mallet, Electro-Magnetic ——— ——— —A mallet for filling teeth, the blows of which are struck by means of electrically driven mechanism.

Electro-magnetism was first employed for this purpose by Bonwill of Philadelphia.

Depolarization.—The act of breaking up or removing the polarization of a voltaic cell or battery. (See *Polarization of Voltaic Cell.*)

Deposit, Electro-Metallurgical ——— —The deposit of metal obtained by electro-metallurgical processes.

To obtain a good metallic deposit the density of the current must be regulated according to the strength of the metallic solution employed.

Electro-metallurgical deposits are either—

(1) *Reguline,* or flexible, adherent, and strongly coherent metallic films, deposited when neither the current nor the solution is too strong.

(2) *Crystalline,* or non-adherent and non-coherent deposits.

The crystalline deposit may either be of a *loose, sandy character,* which is thrown down when too feeble a current is used with too strong a metallic solution, or it may consist of a *black deposit,* which is thrown down when the current is too strong as compared with the strength of the solution. This latter character of deposit is sometimes technically called *burning,* and takes place most frequently at sharp corners and edges, where the current density is greatest. (See *Density of Current.*)

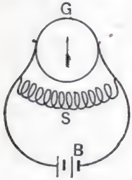


Fig. 130.

Derived Circuit.—A term applied to a *shunt circuit.*

If the conductor S, Fig. 130, be connected with the circuit of the battery B, a derived circuit will thus be established, and a current will flow through S, thus diminishing the current in the galvanometer. (See *Shunt Circuit.*)

Derived Units.—(See *Units, Derived.*)

Destructive Distillation.—(See *Distillation, Destructive.*)

Device, Safety —— for Multiple Circuits.—(See *Safety Catch.*)

Device, Safety —— for Series Circuits.—(See *Device, Safety, for Arc Lamps.*)

Device, Electro-Receptive —— —Various devices placed in an electric circuit, and energized by the passage through them of the electric current.

The following are among the more important electro-receptive devices, viz.:

(1) Electro-Magnet.

(2) Electric Motor,

(3) An Arc or Incandescent Lamp.
(4) An Uncharged Storage Cell.
(5) An Electric Heater.
(6) A Plating Bath, or Voltameter.
(7) A Telegraphic or Telephonic Instrument.
(8) Electro-Magnetic Signal Apparatus.

Dextrorsal Helix.—(See *Helix, Dextrorsal.*)

Diacritical Current.—Such a strength of the magnetizing current as produces a magnetization of an iron core equal to half saturation.

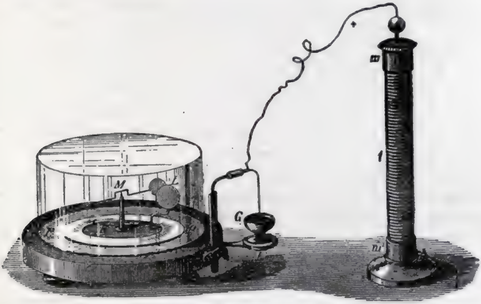


Fig. 131.

Diacritical Number.—Such a number of ampère-turns at which a given core would receive a magnetization equal to half saturation.

Diacritical Point of Magnetic Saturation.—A term proposed by S. P. Thompson for such a value of the *coefficient of magnetic saturation,* that the core is magnetized to exactly one-half its possible maximum of magnetization.

Diagnosis, Electro ——— —The determination of the healthy or diseased condition of different parts of the human body by the character and extent of the muscular contractions on electrical excitation of the nerves or muscles.

Diagometer, Rousseau's ————— —An apparatus in which an attempt is made to determine the chemical composition and consequent purity of certain substances by their electrical conducting powers.

The arrangement of the apparatus is shown in Fig. 131. A dry pile A, has its negative, or —, terminal *m'*, grounded. Its positive, or +, terminal is connected to a delicately supported, and slightly magnetized needle M, terminated by a conducting plate L. Opposite L, and at the same height, is a fixed plate of slightly larger size. The needle M, when at rest in the plane of the magnetic meridian, is in contact at L with the fixed plate. If, therefore, the upper plate of the pile is connected with the needle M both plates are similarly charged and repulsion takes place, the needle coming to rest at a certain distance from the fixed plate.

The substance whose purity is to be determined is placed in the cup G, which is connected through L with the fixed plate. A branch wire from the + terminal of the pile is then dipped into the substance in G, and its purity determined from the length of time required for the two plates at L to be discharged through the material in G.

It is claimed that the instrument will detect the difference between pure coffee and chicory. Its practical application, however, is very doubtful.

Diagram, Thermo-Electric ——— —A diagram in which the thermo-electric power between different metals is designated for different temperatures.

The differences of potential, produced by the mere contact of two metals, varies, not only with the kind of metals, and the physical state of each metal, but also with their temperature. This difference of potential, maintained in consequence of

the difference of temperature between the junctions of a *thermo-electric couple*, is approximately proportional to the differences of temperature of these junctions, if these differences are not great, and is equal to the product of such differences of temperature and a number dependent on the metals in the couple. This number is called the *thermo-electric power*. (See *Couple, Thermo-Electric. Thermo-Electric Power.*)

In Fig. 132 (after Tait), the thermo-electric power is shown between lead and iron, and lead and copper. The numbers at the top of the table represent degrees of the Centigrade thermometer. Those at the sides represent the differences of potential in *micro-volts*.

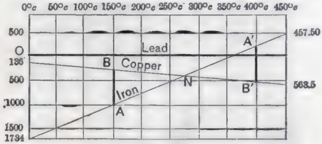


Fig. 132.

The thermo-electric power of the lead-iron couple decreases from the freezing point of water, 0° C., to a temperature of 274°.5 C., when it becomes zero. Beyond that temperature the thermo-electric power increases, but in the opposite direction. The point at which this occurs is called the *neutral point*.

Dial Telegraph.—(See *Telegraphy, Step-by-Step.*)

Diamagnetic.—A term applied to the property possessed by substances like bismuth, phosphorus, antimony, zinc and numerous others, which are apparently repelled when placed between the poles of powerful magnets.

When diamagnetic substances in the form of rods or bars are placed, as in Fig. 134, between the poles A and B of a powerful electro-magnet, they place themselves at right angles to the poles, or are apparently repelled.

Paramagnetic substances like iron or steel, on the contrary, come to rest under similar circumstances in a straight line joining the poles, as in the position shown in the annexed figure.

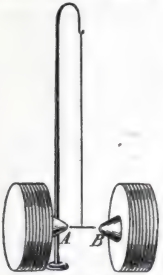


Fig. 134.

Paramagnetic substances are sometimes called *ferro-magnetic*, or substances magnetic after the manner of iron. This word is unnecessary and ill-advised. The term *sidero-magnetic* has also been proposed in place of paramagnetic.

Paramagnetic substances appear to concentrate the lines of magnetic force on them; that is, their magnetic resistance is smaller than that of the air or other medium in which the magnet is placed. They therefore come to rest with their greatest dimensions in the direction of the lines of magnetic force.

Diamagnetic substances appear to have a greater magnetic resistance than that of the air around them. They therefore come to rest with their least dimensions in the direction of the lines of magnetic force.

The difference between paramagnetic and diamagnetic substances is believed by some to be due to the resistance they thus offer to lines of magnetic force as compared with that offered by air or by a vacuum.

The action of magnetism, however, on gaseous media, rotating a plane of polarized light to the right, in some gases, and to the left in others, shows that the real nature of these phenomena is yet unknown.

Tyndall comes to the conclusion as the result of extended experimentation, "that the diamagnetic force is a polar force, the polarity of diamagnetic bodies being opposed to that of

paramagnetic ones under the same conditions of excitement." (See *Tyndall, on Diamagnetism.*)

Diamagnetism is also possessed by certain liquid and gaseous substances.

Diamagnetic Polarity.—(See *Polarity, Diamagnetic.*)

Diamagnetism.—A term applied to the magnetism of diamagnetic bodies. (See *Diamagnetic.*)

Diameter of Commutation.—In a dynamo-electric machine, a diameter on the commutator cylinder on one side of which the differences of potential, produced by the movement of the coil through the magnetic field, tend to produce a current in a direction opposite to those on the other side.

Thus, in Fig. 133, the directions of the induced electro-motive forces are indicated by the arrows. The *diameter of commutation* is therefore the line n n'. The term *neutral line* is also sometimes given to this line.

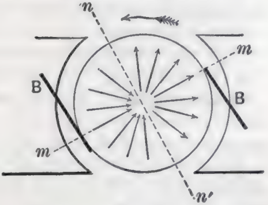


Fig. 133.

It lies at right angles to the line of maximum magnetization.

In an armature with *closed-circuited coils,* that is, in an armature in which the armature coils are connected in a closed circuit, the collecting brushes rest on the commutator cylinder at the *neutral line,* or on the *diameter of commutation.*

In an open circuited armature, however, where the coils are independent of each other, the collecting brushes must be set at m m, at right angles to the neutral line n n. The term *diameter of commutation* is, therefore, often applied to this second position. According to this use of the term, the *diameter of commutation* is that diameter on the commutator which joins the points of contact of the collecting brushes.

The neutral line *n n*, Fig. 133, it will be noticed does not occupy a vertical position, but is displaced somewhat in the direction of rotation, thus necessitating the shifting of the brushes forward in the direction of rotation. This necessary shifting of the brushes is known technically as the *Lead of the Brushes.* (See *Angle of Lead.*)

It will thus be seen that the term diameter of commutation is used in different senses.

In reality, the term refers to the position of certain points on the commutator as distinguished from points on the armature coils. On the commutator, the diameter of commutation is the line drawn through the two commutator bars at which the currents from the two sides are opposed to each other.

It is evident that the commutator may be intentionally twisted with respect to the armature, so as to bring its diameter of commutation into any desired convenient position.

Diaphragm.—A sheet of some solid substance, generally elastic in character and circular in shape, securely fixed at its edges and capable of being set into vibration.

The *receiving diaphragm* of a telephone is generally a rigid plate or disc of iron fixed at its edges, placed near a magnet pole, and set into vibration by variations in the magnetic strength of the pole due to variations in the current that is passed over the line.

The diaphragm of the transmitting telephone, or of a phonograph, consists of a plate, fixed at its edges and set into vibration by the sound waves striking it.

Diaphragm Currents.—Electric currents produced by forcing a liquid through the capillary pores of a diaphragm. (See *Osmose, Electric.*)

Diaphragm of Voltaic Cell.—A term sometimes used for the porous cell of a double fluid voltaic cell. (See *Porous Cell. Cell, Voltaic.*)

Dielectric.—A substance which permits induction to take place through its mass.

The substance which separates the opposite coatings of a condenser is called the dielectric. All dielectrics are non-conductors.

All non-conductors or insulators are dielectrics, but their dielectric power is not exactly proportional to their non-conducting power.

Substances differ greatly in the degree or extent to which they permit induction to take place through or across them. Thus, a certain amount of inductive action takes place between the insulated metal plates of a condenser across the layer of air between them.

Dielectric Capacity, or Dielectric Constant.—A term employed in the same sense as specific inductive capacity. (See *Capacity, Specific Inductive.*)

Dielectric Strain.—The strained condition in which the glass, or other *solid* dielectric of a condenser, is placed by the charging of the condenser.

The *stress* in this case, *i. e.*, the force producing the deformation or *strain*, is the attraction of the opposite charges. This stress, in the case of a Leyden jar, is often sufficiently great to cause a rupture of the glass.

Difference of Potential.—A term employed to denote that portion of the electro-motive force which exists between any two points in a circuit.

The difference of potential at the poles of any electric source, such as a battery or dynamo, is that portion of the total electro-motive force which is available, and is equal to the total electro-motive force, less what is lost in the source. (See *Potential. Electro-Motive Force.*)

Differential Galvanometer.—A galvanometer in which the needle is deflected by the action of two parallel coils, the currents in which are opposed to each other. (See *Galvanometer, Differential.*)

Differential Inductometer.—(See *Inductometer, Differential.*)

Differential Thermo-Pile.—A thermo-pile in which both faces of the pile are exposed to the action of two nearly equal sources of heat in order to determine accurately the difference in their intensities. (See *Thermo-Pile.*)

Differential Voltameter.—(See *Voltameter, Differential.*)

Diffusion of Electric Current.—A term employed mainly in electro-therapeutics to designate the difference in the *density of current* in different portions of the human body, or other conductor.

When the electrodes are placed at any two given points of the human body, the current branches through various paths, extending in a general direction from one electrode to the other, according to the law of branch or derived circuits, and flowing in greater amount, or with greater density of current, through the relatively better conducting paths. (See *Density of Current.*)

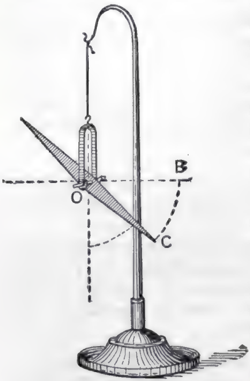


Fig. 135.

Dimensions of Acceleration.—(See *Acceleration, Unit of.*)

Dip, Magnetic.——The deviation of the magnetic needle from a horizontal position.

The inclination of the magnetic needle towards the earth.

The magnetic needle shown in Fig. 135, though supported at its centre of gravity will not retain a horizontal position in all places on the earth's surface.

In the Northern Hemisphere its *north-seeking* end will dip or incline at an angle B O C, called the *angle of dip*. In the Southern Hemisphere its south-seeking end will dip.

The cause of the dip is the unequal distance of the magnetic poles of the earth from the poles of the needle.

The *Magnetic Equator* is a circle passing around the earth midway (in intensity) between the earth's magnetic poles. There is no dip at the magnetic equator. At either magnetic pole the angle of dip is 90°.

Dipping Circle, or Inclination Compass.—A magnetic needle moving freely in a single vertical plane, and employed for determining the angle of dip at any place.

The needle M, Fig. 136, is supported on knife edges so as to be free to move only in the vertical plane of the graduated vertical circle C C. This circle is movable over the horizontal graduated circle H H. In order to determine the true angle of dip, the vertical plane in which the needle is free to move must be placed exactly in the plane of the magnetic meridian.

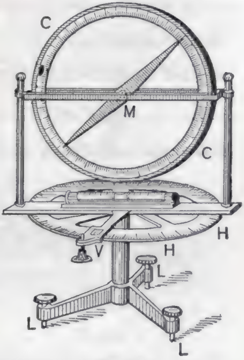


Fig. 136.

To ascertain this plane the vertical circle is moved until the needle points vertically downwards. It is then in a plane 90° from the magnetic meridian. The vertical circle is then moved over the horizontal circle 90°, in which position it is in the plane of the magnetic meridian, when the true angle of dip is read off.

For an explanation of the reason of this see *Component, Horizontal and Vertical, of the Earth's Magnetism.*

Dipping, Electro-Metallurgical Deposition by ———.—The process of obtaining a metallic deposit on a metallic surface by dipping it in a solution of a readily decomposable metallic salt.

A bright, polished iron surface, when simply dipped into a solution of copper sulphate, receives a coating of metallic copper from the electrolytic action thus set up.

This process is known technically as *dipping.* The term dipping is also used in electro-metallurgy to indicate the process of cleaning the articles that are to be electro-plated by dipping them in various acid or alkaline baths.

Direct Current.—(See *Current, Direct.*)

Direct Induced Current.—The current induced in a circuit by induction on itself, or self induction, on breaking the circuit. (See *Extra Current.*)

Direction of Lines of Force.—The direction in which it is assumed the lines of magnetic force pass.

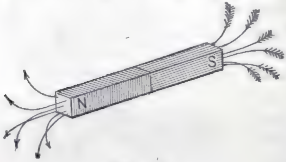


Fig. 137.

It is generally agreed to consider the lines of magnetic force as coming out of the north pole of a magnet and passing into its south pole, as shown in Fig. 137.

This is sometimes called the *positive direction of the lines of force,* and agrees in general with the direction in which the electric current is assumed to flow, which is from the positive to the negative. That is to say, the lines of magnetic force are assumed to flow or pass out of the north pole and into the south pole of a magnet. Of course there is no evidence of any flow, or any particular direction as characterizing them. (See *Field, Magnetic.*)

Directive Power of Magnetic Needle.—The tendency of a magnetic needle to move so as to come to rest in the direction of the lines of the earth's magnetic field.

The directive power of the needle is due to the attraction of the earth's magnetic poles for the poles of the needle, or to the action of the earth's magnetic field. Since the force of the earth's magnetism forms a *couple*, there is no tendency for the needle to move *towards* either of the earth's poles, but merely to rotate until it comes to rest with the lines of the earth's magnetic field passing through its poles. (See *Couple, Magnetic.*)

Of course this would be true in the case of a directing magnet only when it is at a great distance from the needle. Otherwise there would be attraction as well as rotation.

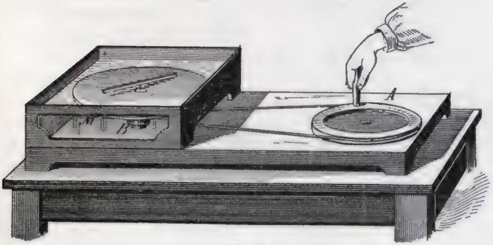


Fig. 138.

Disc, Arago's ——— —A copper or other non-magnetic metallic disc, which, when rapidly rotated under a magnetic needle, supported independently of the disc, causes the needle to be deflected in the direction of rotation, and, when the velocity of the disc is sufficiently great, to rotate with it.

Such a disc is shown in Fig. 138, at B. The movement of the needle is due to electric currents, induced by the disc moving through the field of the needle so as to cut its lines of

magnetic force. To obtain the best results the disc must move very rapidly, and should be near the needle. Moreover, the needle should be very powerful.

This effect was discovered by Arago, in 1824. Since a magnetic needle moving over a metallic plate produces electric currents in a direction which tend to stop the motion of the needle, a damping of the motion of a magnetic needle is sometimes effected by causing it to move near a metal plate. The induced currents which the needle produces in the plate by its motion over it tend to retard the motions of the needle. (See *Damping. Lenz's Law.*)

Disc Armature.—(See *Dynamo-Electric Machine, Armatures.*)

Disc, Faraday's —— —A metallic disc movable in a magnetic field on an axis parallel to the direction of the field.

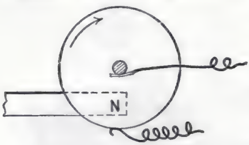


Fig. 139.

Such a disc is shown in Fig. 139, and moves, as will be seen, so as to cut the lines of magnetic force at right angles.

The difference of potential generated by the motion of such a disc may be caused to produce a current, by providing a circuit which is completed through the portion of the disc that at any moment of its rotation is situated between spring contacts resting on the axis of rotation and the circumference of the disc, respectively.

In *Barlow's*, or *Sturgeon's Wheel*, Fig. 140, the wheel itself rotates in the direction shown, when a current is sent through it in a direction indicated by the arrows.

Discharge.—The equalization of the difference of potential between the terminals of a condenser or source, on their connection by a conductor.

The removal of a charge from the surface of any charged conductor by connecting it with the earth, or another conductor, effects its discharge.

The discharge of an insulated conductor, a cloud, a condenser, or a Leyden battery, is but *momentary*, and a current results which rapidly passes from its maximum value to zero.

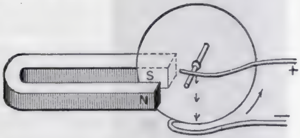


Fig. 140.

The discharge of a voltaic battery, or a storage battery, is nearly continuous, and furnishes a current which is practically continuous, as distinguished from the momentary current produced by the discharge of a condenser.

A discharge may be *Conductive, Convective*, or *Disruptive.*

Discharge, Conductive ——— —A discharge effected by leading the charge off through a conductor placed in contact with the charged body.

Discharge, Convective ——— —The discharge which occurs from the points of a highly charged conductor, through the repulsion by the conductor of air particles that carry off minute charges therefrom.

A convective discharge, though often attended by a feeble sound, is sometimes called a *silent discharge* in order to distinguish it from the *noisy, disruptive discharge*, which is attended by a sharp snap, or, when considerable, by a loud report.

A convective discharge is also called a *glow* or *brush discharge.* The latter is best seen at the small button at the end of the *prime*, or *positive conductor*, of a frictional electric machine.

The *positive discharge* from a point or small rounded conductor is always *brush shaped* ; the *negative* discharge is always *star shaped.*

In rarefied gases, the discharge is convective in character and produces various luminous effects of great beauty, the color of which depends on the kind of gas, and the size, shape, and material of electrodes, and on the degree of the vacuum.

Fig. 141.

Thus, in the rarefied space of the vessel shown in Fig. 141, the discharge, becomes an ovoidal mass of light sometimes called the *Philosopher's Egg.*

When the discharges in rarefied gases follow one another very rapidly, alternations of light and darkness, or *stratification,* or *striæ* are produced.

The breadth of the dark bands increases as the vacuum becomes higher. The light portions start at the positive electrode, and are hotter than the dark portions.

The effects of the luminous convective discharge are best seen in exhausted glass tubes, called *Geissler Tubes,* containing residual atmospheres of various gases. (See *Geissler Tubes.*)

Discharge, Disruptive————The sudden, and more or less complete, discharge that takes place across an intervening non-conductor or dielectric.

A mechanical strain of the dielectric occurs, which *suddenly* permits the discharge to pass as a spark, or rapid succession of sparks.

In air, the spark, when long, generally takes the zigzag path as shown in Fig. 142.

These sparks consist of heated gases, and portions of the conductor that are volatilized by the heat.

The discharge of a Leyden jar or *Condenser*, may be disruptive, as when the discharging rod is held with one knob connected with one coating, and the other near the other coating. It may be gradual, as when the two coatings are alternately connected with the ground.

The *stress* is often sufficient to pierce the glass.

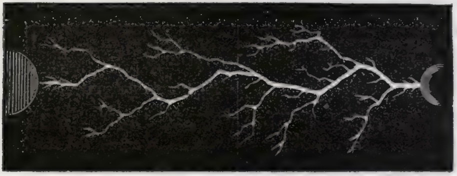


Fig. 142.

Discharge, Duration of ———— —The time required to effect a complete disruptive discharge.

The disruptive discharge is not instantaneous; some time is required to effect it. Estimates of the duration of a flash of lightning, based on the duration of a Leyden jar discharge, are misleading from the enormous difference in the quantity and the potential in the two cases.

Leyden jar discharges, are, however, accomplished in very small periods of time.

Discharge Key.—(See *Key, Discharge.*)

Discharge, Lateral ——— —(See *Lateral Discharge.*)

Discharge, Oscillating ———— —A number of successive discharges and recharges which occur on the disruptive discharge of a Leyden jar, or condenser.

The disruptive discharge of a Leyden jar, or condenser, is not effected by a single rush of electricity. When discharged through a small resistance, a number of alternate partial dis-

charges and recharges occur, which produce true *oscillations* or *undulatory discharges.*

These oscillations are caused by the *induction of the discharge* on itself, and are similar to the mutual induction of a current.

Discharger, Universal ——— —(See *Universal Discharger.*)

Discharging Rod or Tongs.—Metallic rods terminated at one end with balls and connected at the other by a swinging joint, and capable of motion at the free ends towards, or from, one another; employed for the discharge of Leyden batteries or condensers.

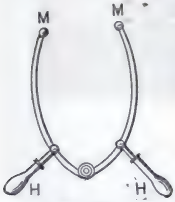


Fig. 143.

The insulated handles H, H, Fig. 143, permit the balls at M M to be readily applied to the opposite coatings of the jar or condenser.

Disconnections. — A term employed to designate one of the varieties of faults caused by the accidental breaking or disconnection of a circuit.

Disconnections of this kind may be :

(1) *Total;* as by a switch inadvertently left open ; or by the accidental breaking of a part of the circuit.

(2) *Partial;* as by a dirty contact; a loose, or badly soldered joint ; a poorly clamped binding screw ; a loose terminal, or a bad earth.

(3) *Intermittent;* as by swinging joints; alternate expansions or contractions, on changes of temperature ; the collection of dust and dirt in dry weather, and their washing out in wet weather.

Dispersion Photometer.—(See *Photometer, Dispersion.*)

Dissimulated or Latent Electricity.—The condition of an electric charge when placed near an opposite charge, as in a Leyden jar or condenser.

In this case, merely touching one of these charged surfaces will not effect its complete discharge. (See *Bound* and *Free Charge.*)

Electricity in the condition of a bound charge was formerly called *latent electricity*. This term is now in disuse.

Dissipation of Charge.—The gradual but final loss of any charge by *leakage*, which occurs even in a well insulated conductor.

This loss is more rapid with negatively charged conductors, than with those positively charged.

Crookes, of England, has retained a charge in conductors for years, without appreciable leakage, by placing the conductors in vessels in which a *high vacuum* was maintained. (See *Vacuum, High.*)

Dissociation.—The separation of a chemica compound into its elementary parts by the action of heat.

Distillation, Dry or Destructive ———— —The action of heat on an organic substance, while out of contact with air, as a result of which the substance is decomposed into simpler and more stable compounds.

The products resulting from the decomposition may be successively collected by the ordinary processes of distillation.

Distillation, Electric ———— —The distillation of a liquid in which the effects of heat are aided by an electrification of the liquid.

Beccaria discovered that an electrified liquid evaporates more rapidly than when unelectrified.

Distribution Box.—(See *Box, Distribution.*)

Distribution of Electric Charge. (See *Charge, Distribution of.*)

Distribution of Electricity, Systems of.—(See *Systems of Distribution by Alternating Currents;—by Direct Currents.*)

Door-Opener, Electric ——— —A device for opening a door from a distance by electricity.

Various devices consisting of electro-magnets, acting against, or controlling, springs or weights, are employed for this purpose.

Double-Carbon Arc Lamp.—An electric arc lamp provided with two pairs of carbon electrodes, so arranged, that when one pair is consumed, the circuit is automatically completed through the other pair.

Double-Contact Key.—(See *Key, Double-Contact.*)

Double-Current, or Reverse Current Working.—The employment, in systems of telegraphy, by means of suitable keys, of currents from voltaic batteries, in alternately opposite directions thus increasing the speed of signaling.

Double-Fluid Electrical Hypothesis.—(See *Electricity, Hypothesis of.*)

Double-Fluid Voltaic Cells.—(See *Voltaic Cells.*)

Double-Refraction.—(See *Refraction, Double.*)

Double-Refraction, Electric ——— —(See *Electric, Double Refraction.*)

Double-Touch, Magnetization by ——— —A method for producing magnetization by the simultaneous touch of two magnet poles. (See *Magnetization, Methods of.*)

Doubler of Electricity.—An early form of *continuous elctrophorus.* (See *Electrophorus.*)

Drill, Electro-Magnetic ——— —A drill, applied especially to blasting or mining operations, operated by means of electricity.

Drum, Electro-Magnetic ——— A drum, used in feats of legerdemain, operated by an automatic electro-magnetic make and break apparatus.

Drum or Cylinder Armature.—An armature for a dynamo-electric machine, in which the coils are wrapped around the outside of a hollow cylindrical or drum-shaped core. (See *Dynamo-Electric Machine, Armatures of.*)

Dry Pile.—A voltaic pile or battery consisting of numerous cells, the voltaic couple in each of which consists of sheets of paper covered with zinc-foil on one side, and black oxide of manganese on the other.

Various modifications of the above are possible.

Duplex Telegraphy.—Devices by means of which two messages can be simultaneously sent over a single wire, in opposite directions. (See *Telegraphy, Duplex.*)

Duration of Electric Discharge.—(See *Discharge, Duration of.*)

Dyad.—A *dyad* or *bivalent element*, is one which has *two bonds* by which it can unite or combine with another element.

An element whose *atomicity* is *bivalent.*

Dyeing, Electric ——— —The application of electricity to the reduction, or the oxidation, of the aniline salts used in dyeing.

Goppelsröder, in his processes of *electro-dyeing,* forms and fixes aniline black on cloths as follows; viz., the cloth, saturated with aniline salt, is placed on an insulated metallic plate, inert to the aniline salt, and connected with one pole of a battery or other electric source. The other pole is connected with a metallic plate on which the required design is drawn. On the passage of the current, the design is traced in aniline black on the cloth. A minute or two suffices for the operation.

A species of electrolytic writing is obtained on cloths arranged as above by substituting a carbon pencil for the metallic plate. On writing with this pencil, as with an ordinary pencil, the passage of the current so directed, is followed by the deposition of aniline black.

By means of a somewhat similar process writing in white on a colored ground is obtained.

Dynamic Attraction.—(See *Attraction, Dynamic.*)

Dynamic Electricity.—A term formerly employed for *current electricity.* Now going out of use.

Dynamics, Electro ————(See *Electro Dynamics.*)

Dynamo Battery.—(See *Battery, Dynamo.*)

Dynamo-Electric Machine.—A machine for the conversion of mechanical energy into electrical energy, by means of electro-magnetic induction.

The term is also applied to a machine by means of which electrical energy is converted into mechanical energy by means of electro-magnetic induction. Machines of the latter class are generally called *motors,* those of the former, *generators.*

A dynamo-electric generator, or a *dynamo-electric machine* proper, consists of the following parts, viz. :

(1) The revolving portion, usually the *Armature,* in which the electro-motive force is developed, which produces the current.

It must be borne in mind that it is not current but *differences of electric potential,* or *electro-motive forces,* that are developed by any electric source from which a current is obtained. For ease of reference, however, we will speak of an electric current as being generated by the armature, or source. No ambiguity will be introduced if the student bears the above in mind.

(2) The *Field Magnets,* which produce the field in which the armature revolves.

(3) The *Pole Pieces,* or free terminals of the field magnets.

(4) The *Commutator,* by which the currents developed in the armature are caused to flow in one and the same direction. In alternating machines and some continuous current dynamos this part is called the *Collector.*

(5) The *Collecting Brushes,* that rest on the *Commutator Cylinder* and take off the current generated in the armature.

Dynamo-Electric Machine, Armature.—The coils of insulated wire and the iron core on or around which the coils are wound.

Armatures are generally divided into the following classes, viz.:

(1) *Ring-Armatures,* in which the armature coils are wound around a ring shaped core, as shown in Fig. 144.

(2) *Drum-Armatures,* in which the armature coils are wound longitudinally over the surface of a cylinder or drum, as shown in Fig. 145.

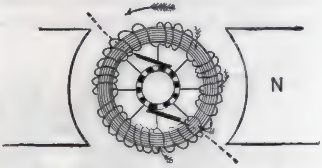


Fig. 144.

(3) *Pole* or *Radial-Armatures,* in which the armature coils are wound on separate poles that project radially from the periphery of a disc, as shown in Fig. 146.

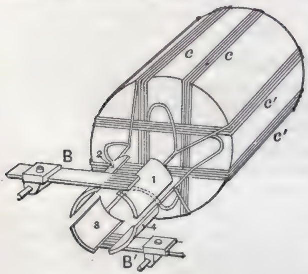


Fig. 145.

(4) *Disc Armatures,* in which flat coils are supported on the surface of a disc.

Dynamos are sometimes divided into Unipolar, Bipolar and Multipolar. A unipolar-armature is one whose polarity is never reversed. A bipolar-armature is one in which the polarity is reversed twice in every rotation; multipolar-armatures have their polarity reversed a number of times in every rotation.

Dynamo-Electric Machine, Armature Coils.—The coils, strips or bars that are wound on the armature core.

To avoid needless resistance the wire should be as short

and thick as will enable the desired current to be obtained without excessive speed of rotation.

The armature coils should enclose as many lines of force as possible (*i. e.*, they should have as nearly a circular outline as possible). In drum-armatures, the breadth should nearly equal the length, unless other considerations prevent.

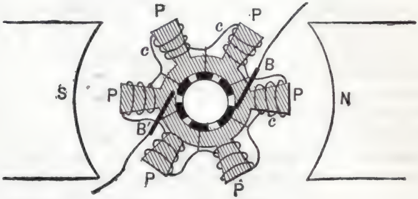


Fig. 146.

When the armature wire consists of rods or bars, it should be laminated or slit in planes perpendicular to the lines of force so as to avoid eddy currents. The greater the number of coils, other things being equal, the more uniform the current generated. The separate coils should be symmetrically disposed, otherwise irregular induction, and consequent *sparking* at the commutator results.

The coils of pole-armatures should be wound near the poles rather than on the middle of the cores. In order to avoid undue heating, spaces for air ventilation are not inadvisable. Various connections of the armature coils are used.

In some machines all the coils are connected in a closed circuit. In some, the coils are independent of one another, and, either for the entire revolution, or for a part of a revolution, are on an open circuit.

In alternating current dynamos in order to obtain the rapid reversals or alternations of current, which in some machines

are as high at 12,000 per minute, a number of poles of alternate polarity are employed. The separate coils that are used on the armature may be coupled either in series or in multiple-arc.

Where a comparatively low electro-motive force is sufficient, such as for incandescent lamps in multiple-arc, the separate coils are united in parallel; but for purposes where a considerable electro-motive force is necessary, as, for example, in systems of alternate current distribution, with convertors at considerable distances from the generating, alternating current dynamo, they are often connected in series, as shown in the Fig. 147.

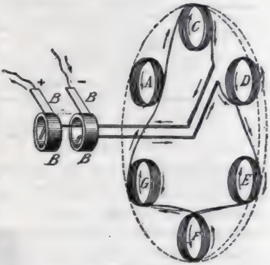


Fig. 147.

Dynamo-Electric Machine, Armature Core.—The iron core, on, or around which, the armature coils are wound.

The armature core is laminated for the purpose of avoiding the formation of *eddy currents.*

In *drum,* and in *ring-armatures,* the laminæ should be in the form of thin insulated discs or plates of soft iron ; in *pole-armatures* they should be in the form of bundles of insulated wires.

The iron in the cores should be of such an area of cross section, as not to be readily oversaturated.

Dynamo-Electric Machine, Cause of Current generated by ——— —*The current developed in the armature coils* is due to the cutting of the lines of magnetic force of the field by the coils during the rotation of the armature.

If a loop of wire, whose ends are connected to the two-part

commutator, shown in Fig. 148, be rotated in the magnetic field between the magnet poles N and S, in the direction of the large arrow, currents will be generated which will flow in the direction indicated by the small arrows during its motion past the north pole from the top to the bottom, but in the opposite direction during its motion past the south pole, from the bottom to the top.

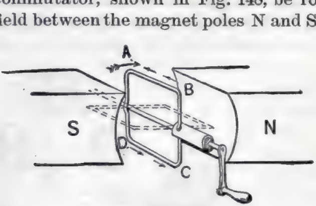


Fig. 148.

S

If now the brushes rest on the commutator in the position shown in the Fig. 149, the vertical line of the gap between the poles corresponding with the vertical gap between the commutator segments, the currents generated in the loop will be caused to flow in one and the same direction, and B′ will become the positive brush since the end of the loop is connected with it only so long as it is positive. As soon as it becomes negative, from the current in the loop flowing in the opposite direction, the other end, which is then positive, is connected with the positive brush.

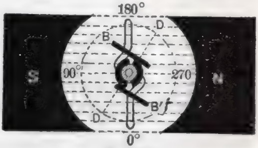


Fig. 149.

Fig. 150.

A similar series of changes occur at the negative brush, B.

Theoretically, the neutral points, where the brushes rest,

would be in the vertical line coinciding with that of the gap between the poles. An inspection of the figure shows that the *Neutral Line*, or the *Diameter of Commutation*, is displaced in the direction of rotation. (See *Diameter of Commutation*). The displacement of the brushes, so necessitated, is called the *lead*. The cause of the lead is the reaction that occurs between the magnetic poles of the field magnets and those of the armature, the result of which is to displace the field magnet poles, and to cause a change in the density in the field. This is shown in Fig. 150, where the density of the lines of force indicates the position of the diameter of commutation as being near *n s*, or at right angles to the diameter of greatest average magnetic density. The *magnetic lag* also influences the positive of the neutral line. (See *Lead. Angle of Lag.*)

Dynamo-Electric Machine, Collecting Brushes. —Metallic brushes which bear on the commutator cylinder, and take off the current generated by the difference of potential in the armature coils. (See *Brushes, Collecting.*)

Dynamo-Electric Machine, Commutator.— The part of a dynamo-electric machine which is designed to cause the alternating currents produced in the armature to flow in one and the same direction in the external circuit.

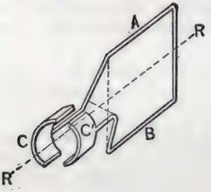


Fig. 151.

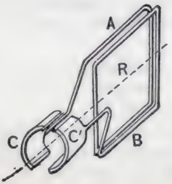


Fig. 152.

The character of the commutator depends on the shape, arrangement, and number of armature coils, and on the character of the magnetic field.

In action, the commutator is subject to wear from the friction of the brushes, and the *burning* action of destructive sparks. The commutator segments are, therefore, made of comparatively thick pieces of metal, insulated from one another, and supported on a commutator cylinder usually placed on the shaft of the armature.

The ends of the armature coils are connected to commutator strips or segments.

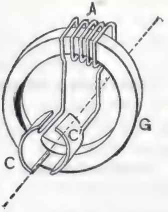


Fig. 153.

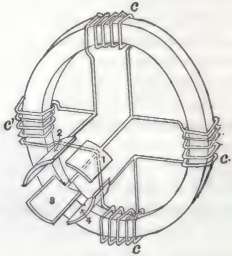


Fig. 154.

Figs. 151, 152, and 153, show the connections of an armature coil to the plates of a *two-part commutator.* (See *Commutator.*)

The connections of a four-part commutator for a ring armature, and the connections of the coils are shown in the annexed Fig. 154.

The commutator strips may either connect the separate coils in one closed circuit, in which the coils are all connected with one another, or, in an open circuited armature, the separate coils are independent of one another.

Dynamo-Electric Machine, Field Magnets.—The electro magnets employed to produce the magnetic field of a dynamo-electric machine.

The field magnets consist of a suitable *frame*, or *core*, on which the *field magnet coils* are wound.

The *field magnet cores* are made of thick and solid iron, as soft as possible. They should contain plenty of iron in order to avoid too ready *magnetic saturation*.

All edges and corners are to be avoided, since they tend to cause an irregular distribution of the field.

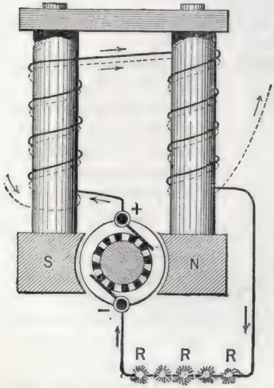


Fig. 155.

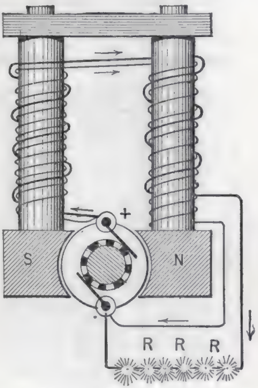


Fig. 156.

The field magnets should have sufficient magnetic strength to prevent the magnetizing effect of the armature from unduly influencing the field, and thus, by causing too great a *lead*, produce injurious *sparking*.

Dynamo-Electric Machine, Methods of Increasing the Electro-Motive Force generated by —— —The electro-motive force of a dynamo-electric machine may be increased in the following ways, viz.:

(1) By increasing its Speed of Rotation.

(2) By increasing the Strength of the Magnetic Field between which the armature rotates.

(3) By increasing the Size of the Field through which the armature passes in unit time, the intensity remaining the same.

(4) By increasing the Number of Armature Windings, *i. e.*, by making successive parts of the same wire pass simultaneously through the field.

(5) By increasing the Number of Fields passed through by the same wire.

Dynamo-Electric Machine, Pole Pieces.—Massive pieces of iron placed on the poles of the field magnets of dynamo-electric machines, to define and limit the magnetic field.

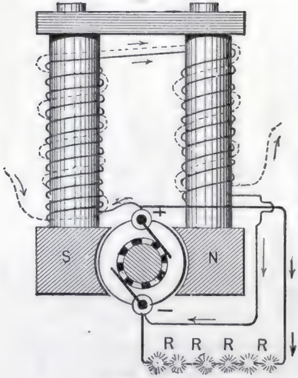


Fig. 157.

The pole pieces should be of massive, soft iron. They are sometimes laminated so as to avoid eddy currents. When designed to produce a uniform field they must extend on each side of the armature, but not too far, else a loss will be occasioned by the lines of magnetic force closing directly through the edges of the opposite pole pieces, instead of through the armature.

Dynamo-Electric Machines, Compound Wound ——— —Machines whose field magnets are excited by more than one circuit of coils, or by more than a single electric source.

Compound dynamos are of two classes, viz.:

(1) Those designed to produce a Constant Potential, and

(2) Those designed to produce a Constant Current.

For Constant Potential.

The combination of a *Series* and *Separately Excited* machine is shown in Fig. 155. The field is in series with the armature, but has also an additional and separate excitation.

The combination of a *Series* and *Shunt* machine ensures the excitation of the field both by the main and by a shunted current. Such a combination is shown in Fig. 156.

For Constant Current.

The combination of *shunt* and *separately excited* machine is shown in Fig. 157. In this machine the field is excited by means of a shunt to the external circuit, and by a current produced by a separate source.

The combination of a *Series* and *Magneto Machine* is shown in Fig. 159. This, also, is designed to give a constant current.

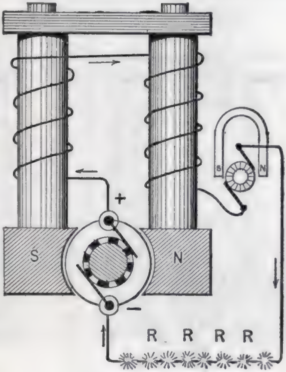


Fig. 158.

Dynamo-Electric Machines, Varieties of —— — *Dynamo-electric* machines may be divided into different classes according to the manner in which their field magnets are excited.

In a *Series Dynamo*, Fig. 159, the armature circuit is connected in series with the field circuit; therefore the entire armature current must pass through the field coils.

In a *Shunt Dynamo*, Fig. 160, the field magnet coils are placed in a shunt to the external circuit, so that only a portion of the current generated in the armature passes through the field magnet coils, but all the difference of potential of the armature acts at the terminals of the field circuit.

In a *Separately Excited Dynamo*, Fig. 161, the field magnet coils have no connection with the armature coils, but receive their current from a separate machine or source.

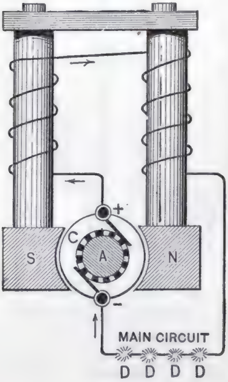


Fig. 159.

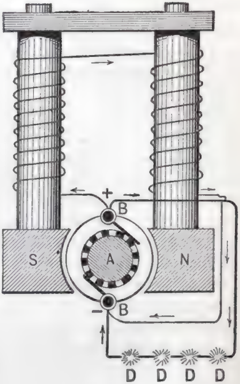


Fig. 160.

The *Magneto-Electric* machine, Fig. 162, has no field magnet coils, its field being due to permanent steel magnets.

The author has collated the above on dynamo-electric machines largely from S. P. Thompson's admirable book on "Dynamo-Electric Machinery," third edition, to which the student is referred for further particulars of construction or

operation. He is also indebted to Hering's "Principles of Dynamo-Electric Machines."

Dynamograph.—A term sometimes applied to a type-writing telegraph that records the message in type-written characters, both at the sending and the receiving ends.

Dynamometer.—A name given to a variety of apparatus for measuring the power of an engine or motor.

In all dynamometers, the stress on the belt, or other moving part, is measured, say in pounds, and the speed of the moving part is also measured in feet per second. The product of the strain in pounds by the velocity in feet per second, divided by 550, will give the horse power.

One of the many forms of dynamometers is shown in Fig. 163. It is known as Parsons' Dynamometer.

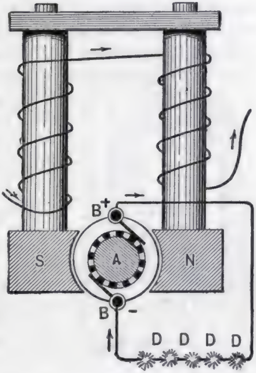


Fig. 161.

The driving pulley is shown at A, and the driven pulley at C. Weights hung at Q are varied so as to maintain the axes of the suspended pulleys, D and B, as nearly as possible at the same height. Then the tension T_1 and T_2, of the sides O and O', of the belts, will be represented by the following equation:

$T_2 - T_1 = \frac{P - Q}{2}$, from which, knowing the belt speed, the horse power may be deduced.

Dynamometer, Electro ——.—A form of galvanometer for the measurement of electric currents.

In Siemens' Electro Dynamometer, shown in Fig. 164, there are two coils; a fixed coil C, secured to an upright support, and a movable coil D ,consisting often of but a single turn of wire. The movable coil is suspended by means of a thread and a delicate spring S, capable of being twisted by turning a milled screw-head through an angle of torsion measured on a scale by means of an index connected to the screw-head. The two ends of the movable coil dip into mercury cups so connected that the current to be measured passes through the fixed and movable coils in series.

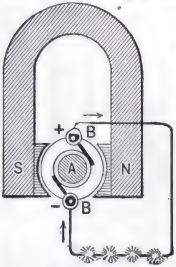


Fig. 162.

When ready for use, the movable coil is at right angles to the fixed coil. The current to be measured is then sent into the coils, and their mutual action tends to place the movable coil parallel to the fixed coil against the torsion of the spring S. The amount of this force can be ascertained by determining the amount of torsion required to bring the movable coil back to its zero position.

Since the same current passes through both the fixed and movable coils, and they both act on each other, the deflecting force here is evidently proportional to the square of the strength of the current to be measured. The deflecting force, and consequently the current strength, is therefore proportional to the square root of the angle of torsion, and not directly to the angle of torsion.

Dyne.—The unit of force.

The force which in one second can impart a velocity of one centimetre per second to a mass of one gramme.

Earth Circuit or Ground Circuit.—(See *Circuit, Grounded.*)

Earth Currents.—Electric currents flowing through different parts of the earth caused by a difference of potential at different parts.

The causes of these differences of potential are various.

Earth, Dead or Solid ——— —(See *Earths.*)

Earth or Ground.—The earth or ground which forms part of an electric circuit.

A circuit is put to *earth* or *ground* when the earth is used for a portion of the circuit.

The resistance of an earth connection may vary in time from the following causes, viz.:

(1) The corrosion of the plate. This is especially apt to occur in the case of a copper plate.

(2) From polarization, a counter electro-motive force being produced, thus introducing a *spurious resistance.* (See *Spurious Resistance.*)

Earth, Partial ——— —(See *Earths.*)

Earth, Swinging ——— —(See *Earths.*)

Earths.—Faults in telegraph or other lines caused by accidental contact of line with the ground or earth.

Earths are of three kinds, viz.:

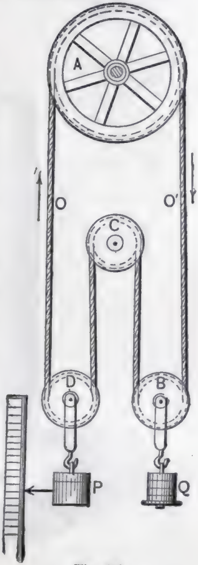


Fig. 163.

(1) *Total,* or *Dead Earth,* where the wire is thoroughly grounded or connected with the earth.

(2) *Partial Earth,* or where the wire is in imperfect connection with the earth.

(3) *Intermittent Earth*, or when the wire makes intermittent contact with the earth by the action of the wind, or by occasional expansion by heat.

Ebonite or Vulcanite.—A black variety of hard rubber which possesses high powers of insulation and specific inductive capacity.

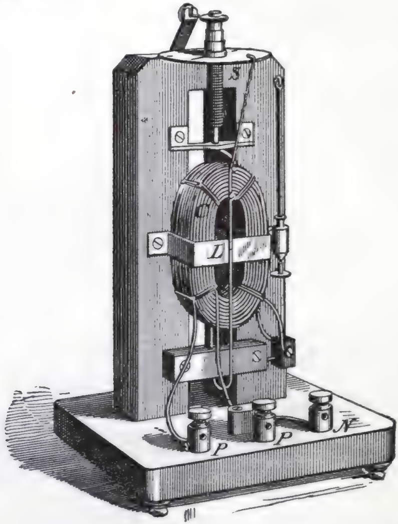


Fig. 164.

Vulcanite rubbed with cat-skin acts as one of the best known substances for becoming electrified by friction. For this purpose it should be thoroughly dried.

Economic Coefficient, or Efficiency of a Dynamo. —(See *Coefficient, Economic, of a Dynamo.*)

Effect, Edison ——— —An electric discharge between one of the terminals of the incandescent filament of the electric lamp, and a metallic plate placed near the filament but disconnected therefrom, as soon as a certain difference of potential is reached between the lamp terminals.

The effect of the discharge is to produce a current in a circuit connected to one pole of the lamp terminals and the metallic plate, as may be shown by means of a galvanometer.

Effect, Hall ——— —An effect produced by placing a very thin metallic strip, conveying an electric current, in a strong magnetic field.

The cross A B C D, Fig. 165, is cut out of a gold leaf or other very thin metallic sheet. The ends A and B are connected with the terminals of a battery S, and C and D with the galvanometer G.

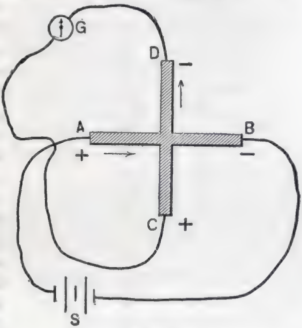


Fig. 165.

None of the battery current can therefore flow through the alvanometer.

If, now, the metallic cross be placed in a powerful magnetic field, the lines of force of which are perpendicular to the plane of the cross, the deflection of the galvanometer needle will show the existence of a current, which, if the battery current flows in the direction of the arrow, or from A to B, if the lines of magnetic force pass through the leaf from the *front to the back of the sheet,* when the cross is formed of gold, silver,

platinum or tin-foil, will flow through C D, from C to D, but in the opposite direction if formed of iron. These effects cease if the conductor is increased in thickness beyond a certain extent.

Effect, Joule ——— —A term applied to the heat developed in a conductor by the passage through it of an electric current.

The rate at which this occurs is proportional to the *resistance of the conductor* multiplied by the *square of the current.* (See *Heat, Electric.*)

Effect, Peltier ——— —The heating effect produced by the passage of an electric current across a *thermo-electric junction.* (See *Junction, Thermo-Electric.*)

The passage of the current across a thermo-electric junction produces either heat, or cold. If *heat* is produced by its passage in *one direction, cold* is produced by its passage in the *opposite direction.* The Peltier effect may, therefore, mask the Joule effect.

The *Peltier effect* is therefore the converse of the *thermo-electro effect,* where the uneqal heating of metallic junctions produces an electric current. (See *Effect, Joule ; Effect, Thomson.*)

The quantity of heat absorbed or emitted by the Peltier effect is proportional to the current strength, and not, as in the Joule effect, to the square of the current.

Effect, Photo-Voltaic ——— —(See *Photo-Voltaic Effect. Selenium Cell.*)

Effect, Thomson ——— —A term applied to the increase or decrease in the differences of temperature is an *unequally* heated conductor, produced by the passage of an electrical current through the conductor.

The effects vary according to whether the current passes from a colder to a hotter part of the wire, or the reverse.

These effects differ in direction in different metals, and

are absent in lead. Thomson has pointed out the similarity between this species of thermo-electric phenomena, and *convection by heat*, or the phenomena of a liquid circulating in a closed rectangular tube, under the influence of difference of temperature, *in which the heated fluid gives out heat in the cooler parts of the circuit, and takes in heat in the warmer parts.* This would presuppose that positive electricity carries heat in copper like a real fluid, but that in iron it acts as though its specific heat were a negative quantity, in which respect it is unlike a true fluid.

"We may express" says Maxwell "both the Peltier and the Thomson effects by stating that when an electric current is flowing from places of smaller to places of greater thermo-electric power, heat is absorbed, and when it is flowing in the reverse direction heat is generated, and this whether the difference of thermo-electric power in the two places arises from a difference in the nature of the metal, or from a difference of temperature in the same metal."

Efficiency of Conversion of Dynamo ——.—The total electric energy developed by a dynamo, divided by the total mechanical energy required to drive the dynamo. (See *Coefficient, Economic, of Dynamo.*)

Efficiency of Dynamo.—(See *Coefficient, Economic of Dynamo.*)

Efflorescence.—The crystallization of a salt, above the line of liquid, on the surface of a vessel containing a saline solution.

The liquid, by capillarity in a porous vessel, or by adhesion in an impervious vessel, rises above the level of the main liquid line and, evaporating, deposits crystals on the vessel.

This process is technically called *creeping*, and is often the cause of much annoyance in voltaic cells.

Egg, Philosopher's ——.—(See *Discharge, Convective.*)

Electric Absorption.—(See *Absorption, Electric.*)

Electric Alarm.—(See *Alarm, Electric.*)

Electric Amalgam.—(See *Amalgam, Electric.*)

Electric Analysis.—(See *Analysis, Electric.*)

Electric Annealing.—A process for annealing metals, in which electric heating is substituted for ordinary heating.

Electric Battery.—(See *Battery, Electric.*)

Electric Blasting.—(See *Blasting, Electric.*)

Electric Bleaching.—(See *Bleaching, Electric.*)

Electric Blow-Pipe.—(See *Blow-Pipe, Electric.*)

Electric Boat.—(See *Boat, Electric.*)

Electric Bobbin.—(See *Bobbin, Electric.*)

Electric Body Protector. — (See *Body Protector, Electric.*)

Electric Boiler Feed.—(See *Boiler Feed, Electric.*)

Electric Bridge.—(See *Bridge, Electric.*)

Electric Buoy.—(See *Buoy, Electric.*)

Electric Burner.—(See *Burner, Electric.*)

Electric Buzzer.—(See *Buzzer, Electric.*)

Electric Calorimeter.—(See *Calorimeter, Electric.*)

Electric Cautery.—(See *Cautery, Electric.*)

Electric Charge.—(See *Charge, Electric.*)

Electric Chimes.—(See *Chimes, Electric.*)

Electric Chronograph.—(See *Chronograph, Electric.*)

Electric Chronoscope.—(See *Chronoscope, Electric.*)

Electric Clepsydra.—(See *Clepsydra, Electric.*)

Electric Clock.—(See *Clock, Electric.*)

Electric Coil.—(See *Coil, Electric.*)

Electric Column.—(See *Column, Electric.*)

Electrically Controlled Clock.—(See *Clock, Controlled.*)

Electric Controlling Clock.—(See *Clock, Controlling.*)

Electric Convection of Heat.—(See *Convection of Heat, Electric.*)

Electric Cords.—(See *Cords, Electric.*)

Electric Counter.—(See *Counter, Electric.*)

Electric Cross.—(See *Cross, Electric.*)

Electric Crucible.—(See *Crucible, Electric.*)

Electric Current.—(See *Current, Electric.*)

Electric Decomposition.—(See *Decomposition, Electric.*)

Electric Deposition.—(See *Deposition, Electric.*)

Electric Distillation.—(See *Distillation, Electric.*)

Electric Double Refraction.—The transient or momentary power of *double refraction*, acquired by a transparent substance when placed in an electric field. (See *Refraction, Double.*)

The intensity of the double refraction is proportional to the square of the electric force.

This action is due to the strain caused by the *electrostatic stress* produced by the field. A similar transient power of double refraction is acquired by many transparent bodies when subjected to simple mechanical stress.

Fig. 166.

Electric Dyeing.—(See *Dyeing, Electric.*)

Electric Dynamometer, Siemens'.—(See *Dynamometer, Electro.*)

Electric Eel (*Gymnotus electricus.*)—An eel possessing the power of giving powerful electric shocks.

The electricity is produced by an organ extending the entire length of the body.

According to Faraday, the shock given by a specimen of the animal examined by him was equal to that of 15 Leyden jars, having a total surface of 25 square feet. Fig. 166 shows the general appearance of the animal.

Electric Energy.—(See *Energy, Electric.*)

Electric Entropy.—(See *Entropy, Electric.*)

Electric Escape.—(See *Escape, Electric.*)

Electric Etching.—(See *Etching, Electric.*)

Electric Excitability of Nerve Fibre.—(See *Excitability of Nerve Fibre.*)

Electric Expansion.—(See *Expansion, Electric.*)

Electric Explorer.—(See *Explorer, Electric.*)

Electric Field.—A field of force, traversed by imaginary lines of force somewhat similar to the magnetic field. (See *Field, Electric.*)

Electric Figures, Breath.—(See *Figures, Electric, Breath.*)

Electric Figures, Lichtenberg's.—(See *Figures, Electric, Lichtenberg's.*)

Electric Fishes.—(See *Fishes, Electric.*)

Electric Flyer, or Fly.—(See *Flyer, Electric.*)

Electric Fog.—(See *Fog, Electric.*)

Electric Force.—The force developed by electricity.

This term is generally limited to the force of attraction or repulsion produced by an electrostatic charge.

Electric Furnace.—(See *Furnace, Electric.*)

Electric Fuse.—(See *Fuse, Electric.*)

Electric Gas Lighting.—(See *Gas Lighting, Electric.*)

Electric Gilding.—(See *Gilding, Electric.*)

Electric Governor.—(See *Governor, Electric.*)

Electric Head Light.—(See *Head Light, Electric.*)

Electric Heat.—(See *Heat, Electric.*)

Electric Heater.—(See *Heater, Electric.*)

Electric Horse Power.—(See *Horse Power, Electric.*)

Electric Hydrotasimeter.—(See *Hydrotasimeter, Electric.*)

Electric Ignition.—(See *Ignition, Electric.*)

Electric Images.—(See *Images, Electric.*)

Electric Incandescence.—(See *Incandescence, Electric.*)

Electric Indicators.—(See *Indicators, Electric.*)

Electric Insolation.—(See *Sunstroke, Electric.*)

Electric Jewelry.—(See *Jewelry, Electric.*)

Electric Lamp, Arc.—(See *Lamp, Electric, Arc.*)

Electric Lamp, Incandescent.—(See *Lamp, Incandescent.*)

Electric Lamp, Semi-Incandescent.—(See *Lamp, Semi-Incandescent.*)

Electric Letter-Box.—(See *Letter-Box, Electric.*)

Electric Locomotive.—(See *Locomotive, Electric.*)

Electric Log.—(See *Log, Electric.*)

Electric Loop.—(See *Loop, Electric.*)

Electric Machines, Electrostatic Induction ———(See *Machines, Electrostatic Induction.*)

Electric Machines, Frictional ————(See *achin Electric, Frictional.*)

Electric Mains.—(See *Mains, Electric.*)

Electric Masses.—(See *Masses, Electric.*)

Electric Measurement.—(See *Measurement, Electric.*)

Electric Meter.—(See *Meter, Electric.*)

Electric Mine Exploder.—(See *Fuse, Electric.*)

Electric Motor.—(See *Motor, Electric.*)

Electric Musket.—(See *Musket, Electric.*)

Electric Organ.—(See *Organ, Electric.*)

Electric Oscillations.—(See *Oscillations, Electric.*)

Electric Osmose.—(See *Osmose, Electric.*)

Electric Pen.—(See *Pen, Electric.*)

Electric Pendulum.—(See *Pendulum, Electric.*)

Electric Phosphorescence.—(See *Phosphorescence, Electric.*)

Electric Piano.—(See *Piano, Electric.*)

Electric Plough.—(See *Plough, Electric.*)

Electric Potential.—(See *Potential, Electric.*)

Electric Probe.—(See *Probe, Electric.*)

Electric Prostration.—(See *Sunstroke, Electric.*)

Electric Protection.—(See *Lightning Rods.*)

Electric Protection of Metals.—(See *Metals, Electric Protection.*)

Electric Pyrometer.—(See *Pyrometer, Electric.*)

Electric Ray (*Raia torpedo*).—A species of fish named the ray, which, like the electric eel, possesses the power of producing electricity.

The electric organ is situated at the back of the head, and consists of hundreds of polygonal, cellular laminæ, supplied with numerous nerve fibres, as shown in Fig. 167.

Electric Rectification of Alcohol.—(See *Alcohol, Electric Rectification of.*)

Electric Register, Watchman's ————(See *Watchman's Electric Register.*)

Electric Registering Apparatus.—(See *Registering Apparatus, Electric.*)

Electric Resistance.—(See *Resistance, Electric.*)

Electric Safety Lamp.—(See *Safety Lamp, Electric.*)

Electric Seismograph.—(See *Seismograph, Electric.*)

Electric Shadow.—(See *Shadow, Electric.*)

Electric Shock.—(See *Shock, Electric.*)

Electric Socket for Lamp.—(See *Socket, Electric Lamp.*)

Electric Soldering.—(See *Soldering, Electric.*)

Electric Storms.—(See *Storms, Electric.*)

Electric Striæ.—(See *Striæ, Electric.*)

Electric Sunstroke.—(See *Sunstroke, Electric.*)

Electric Target.—(See *Target, Electric.*)

Electric Teazer.—(See *Teazer, Electric Current.*)

Electric Tempering.—A process for tempering metals in which heat of electric origin is employed instead of ordinary furnace heat. (See *Tempering, Electric.*)

Fig. 167.

Electric Tension.—(See *Tension, Electric.*)

Electric Thermometer.—(See *Thermometer, Electric.*)

Electric Time-Ball.—(See *Time-Ball, Electric.*)

Electric Torpedo.—(See *Torpedo, Electric.*)

Electric Tower.—(See *Tower, Electric*)

Electric Transmitters.—(See *Transmitters, Electric.*)

Electric Typewriter.—(See *Typewriter, Electric.*)

Electric Valve.—(See *Valve, Electric.*)

Electric Varnish.—(See *Varnish, Electric.*)

Electric Welding.—(See *Welding, Electric.*)

Electric Whirl.—(See *Whirl, Electric.*)

Electric Whistle.—(See *Whistle, Steam, Electric.*)

Electric Work.—(See *Work, Electric.*)

Electrical Convection of Heat.—A term employed to express the dissymmetrical distribution of temperature that occurs when a current of electricity is sent through a metallic wire, the middle of which is maintained at a constant temperature, and the ends at the temperature of melting ice.

Electrical Death.—(See *Death, Electrical.*)

Electricity.—The name given to the unknown thing, matter, or force, or both, which is the cause of electric phenomenon.

Electricity, no matter how produced, is believed to be one and the same thing.

The terms *frictional electricity, pyro-electricity, magneto electricity, voltaic or galvanic electricity, thermo-electricity, contact electricity, animal or vegetable electricity,* etc., etc., though convenient for distinguishing their origin, have no longer the significance formerly attributed to them as representing different kinds of the electric force. (See *Electricity, Hypotheses of.*)

Electricity, Conservation of————A term proposed by Lippman, to express the fact that when a body receives an electric charge in the open air, the earth and heavenly bodies receive an equal and opposite charge, thus preserving

the sum of the total positive and negative electricities in the universe.

Electricity, Double Fluid Hypothesis of.—A hypothesis which endeavors to explain the cause of electric phenomena by the assumption of two different electric fluids.

The Double Fluid Electric Hypothesis assumes:

(1) That the phenomena of electricity are due to two tenuous and *imponderable* fluids, the positive and the negative.

(2) That the particles of the positive fluid repel one another, as do also the particles of the negative fluid; but that the particles of positive fluid attract the particles of the negative, and *vice versa.*

(3) That the two fluids are strongly attracted by matter, and when present in it produce electrification.

(4) That the two fluids attract one another and unite, thus masking the properties of each.

(5) That the act of friction separates these fluids, one going to the rubber and the other to the thing rubbed.

Electricity, Single Fluid Hypothesis of.—A hypothesis which endeavors to explain the cause of electrical phenomena by the assumption of a single electric fluid.

The single-fluid hypothesis assumes:

(1) That the phenomena of electricity are due to the presence of a single, tenuous, imponderable fluid.

(2) That the particles of this fluid mutually repel one another, but are attracted by all matter.

(3) That every substance possesses a definite capacity for holding this fluid, and, that when this capacity is just satisfied no effects of electrification are manifest.

(4) That when the body has less than this quantity present, it becomes *negatively excited,* and when it has more, *positively* excited.

(5) That the act of friction causes a redistribution of the fluid, part of it going to one of the bodies, giving it a surplus,

and thus positively electrifying it, and leaving the other with a deficit, and thus negatively electrifying it.

Neither of these hypotheses is accepted at the present time, electrical science having advanced sufficiently far to recognize the fact that the exact nature of electricity is unknown.

By some, electricity is believed to consist, like heat, of a particular phase of energy ; by others it is regarded as an exceedingly tenuous form of matter ; by still others, the exceedingly strange assumption is made that it is neither a phase of energy nor a form of matter.

By some, the single fluid hypothesis is provisionally accepted with this modification, that a negatively excited body is thought to be the one which contains the *excess* of the assumed fluid, and a positively excited body the one which contains the *deficit.*

This change in the single fluid hypothesis is believed to be necessitated by the fact observed in *Crooke's tubes,* that the molecules of residual gas are thrown off from the *negative terminal,* and not from the *positive* terminal. (See *Tubes, Crooke's.*)

Another view, which has long been held by the author, attributes the phenomena of electricity to differences of ether pressures, electricity itself being the ether, and the electromotive force the differences of pressure of the ether. That one form of electrification, possibly negative, is caused by a *surplusage of energy* charged on the excited body, thus producing a greater ether tension or pressure, and the opposite electrification, by a *deficit of energy,* thus producing a smaller ether tension or pressure.

It will be seen that the assumptions as to the direction of the current, and the positive direction of the lines of force, are based on the old idea that positive electrification indicates an excess, and negative electrification a deficit.

Electricity, Bound and Free, Disguised, Dissimulated, or Latent ——— (See *Bound and Free Charge.*)

Electrics.—Substances capable of becoming electrified by friction.

Substances like the metals, which, when held in the hand could not be electrified by friction were called *non-electrics.*

These terms were used by Gilbert in the early history of the science.

This distinction is not now generally employed, since conducting substances may be electrified by friction, if insulated.

Electrification.—The act of becoming electrified.

Electrification generally refers to the production of an electric charge.

Electro-Biology.—The study of the electric conditions of living animals and plants, or the effects of electricity upon them.

Electro-Biology includes :

(1) Electro-Physiology.

(2) Electro-Therapy, or Electro-Therapeutics.

Electro-Capillary Phenomena. — Phenomena observed in capillary tubes at the contact surfaces of two liquids.

In the case where acidulated water is in contact with mercury, each liquid possesses a definite surface tension, and each a definite shape of surface.

The two liquids, however, do not actually touch, there being a small interval or space between them. This space acts as an *accumulator*. But the liquid and water, being different substances in contact, possess different potentials. (See *Accumulator*, or *Condenser. Contact, Electricity. Potential.*)

Any cause which alters the shape of these contact surfaces, and consequently the extent of the spaces between them, necessarily alters the *capacity* of the condenser, and consequently the difference of potential. Therefore the mere shaking of the tube, or heating it, will produce electric currents from the resulting differences of potential; or, conversely, an electric current sent across the contact-surfaces will produce motion as a result of a change in the value of

the *surface tension.* An *Electro-Capillary Telephone* has been constructed on the former principle, and an *Electrometer* on the latter. (See *Capillary Electrometer. Telephone, Electro-Capillary.*)

Electro-Chemistry.—That branch of electric science which treats of chemical compositions and decompositions produced by the electric current. (See *Electrolysis,* or *Electrolytic Decomposition.*)

Electrode, Indifferent ———— —In electro-therapeutics the electrode that is merely employed to complete the circuit through the organ or part subjected to the electric current, and is not directly concerned in the treatment or diagnosis of the diseased parts.

Either the positive or the negative electrode may be the indifferent electrode. (See *Electrode, Therapeutic.*)

Electrode, Therapeutic ———— —In electro-therapeutics the electrode mainly concerned in the treatment, or diagnosis of the diseased parts.

Either the positive or the negative electrode may be the therapeutic electrode, and one or the other is employed according to the particular character of the effect it is desired to obtain. The other electrode is placed at any convenient and suitable part of the body, and is called the *indifferent electrode.*

The therapeutic electrode is generally placed nearer the organ or part to be treated than the indifferent electrode.

Electrodes.—The terminals of an electric source.

The positive electrode is sometimes called the *Anode,* and the negative electrode the *Kathode.* In precise use these terms are generally restricted to the electrodes when used for electrolytic decomposition.

The electrodes are made of different shapes and of different materials according to the character of the work the current is to perform.

The *carbon electrodes* of an arc lamp are provided for the formation and maintenance of the *voltaic arc*. In electro-therapeutics, *clay electrodes, sponge electrodes, brush electrodes, disc electrodes, needle electrodes, dry* or *moist electrodes, urethral electrodes, aural electrodes, vaginal electrodes, rectal electrodes*, etc., etc., are employed, and are named according to the nature of the work required to be accomplished, or the particular organ or part of the body that is to be treated.

Electrodes, Erb's Standard Size of———.—Standard sizes of electrodes generally adopted in electro-therapeutics.

The following standard sizes have been proposed by Erb, viz.:

(1) Fine	electrode	½	centimetre	diameter.
(2) Small	"	2	"	"
(3) Medium	"	7.5	"	"
(4) Large	"	6 × 2	"	"
(5) Very large	do.	8 × 16	"	"

Electro-Diagnosis.—Diagnosis by means of the exaggeration or diminution of the reaction of the excitable tissues of the body when subjected to the varying influences of electric currents.

The electric current has also been applied in order to distinguish between forms of paralysis, and as a final test of death.

Electro-Dynamic Induction.—(See *Induction, Electro-Dynamic.*)

Electro-Dynamics.—That branch of electric science which treats of the action of electric currents on one another and on themselves.

The principles of electro-dynamics were discovered by Ampère in 1821.

A convenient form of apparatus, for showing experimentally the action of one current on another, consists of two upright metallic columns or pillars, which support horizontal metallic arms containing mercury cups, *y* and *c*, Fig. 168. The circuit

is bent in the form of a rectangle, circle, or solenoid, and terminates in points that dip in the mercury cups. The current is led into and out of the apparatus at the points + and — at the base of the upright supports.

When, now, a magnet, or another circuit, is approached to the movable circuit thus provided, attractions or repulsions are produced according to the position of the magnet, or the direction of the currents in the two circuits.

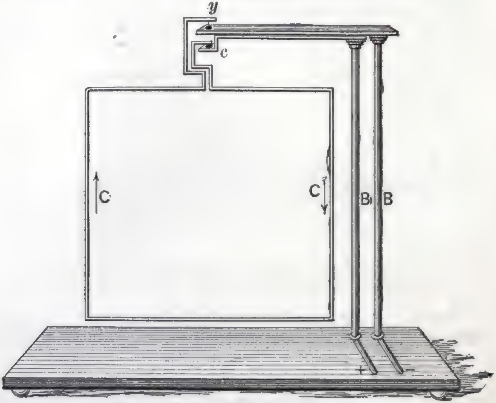


Fig. 168.

If a magnet A B, Fig. 169, be placed, as shown, below the movable circuit C C, the circuit will tend to place itself at right angles to the axis of the magnet. This movement is the same as would occur if electric currents were circulating around the magnet in the direction of the assumed *Ampèrian currents.* (See *Magnetism, Ampère's Theory of.*)

Ampère has given the results of his investigations in the following statements, which are known as *Ampère's Laws*:

(1) Parallel portions of a circuit attract one another if the currents in them are flowing in the same direction, and repel one another if the currents are flowing in opposite directions.

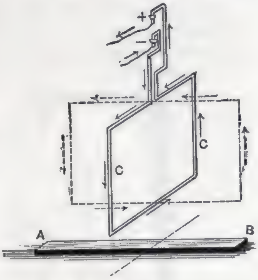


Fig. 169.

A current flowing through a spiral tends to shorten the spiral from the attraction of the parallel currents in contiguous turns.

Similar poles of two solenoids repel each other, as at A, A′, Fig. 170, because, when opposed to each other, the currents that produce these poles are flowing in opposite directions, as may be seen from an inspection of the drawing.

Dissimilar solenoid poles, on the contrary, attract each other as at A, B, in the figure, since the currents which produce them flow in the same direction.

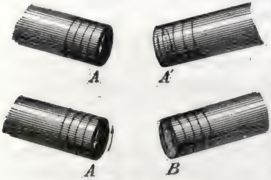


Fig. 170.

In Fig. 171, a form of Ampère's stand is shown, in which one of the circuits is in the form of the helix M N; its action on the movable circuit C B, is to repel it, since the currents, as shown, are flowing in opposite directions in the approached portions of the fixed and movable circuits.

(2) Two portions of a circuit intersecting each other mu-

tually attract each other when the currents in both circuits flow either *towards* or *from* the point of intersection, but repel each other if they flow in opposite directions from the point.

Thus, in Fig. 172, the currents in both circuits flow towards and from the point of intersection Y, and attract one another and cause a motion *until the two circuits are parallel.*

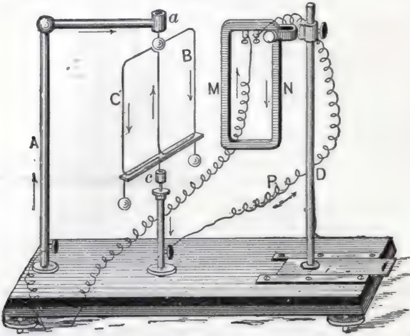


Fig. 171.

If the currents flow in opposite directions they repel one another, and, if free to move, will come to rest when parallel to each other; therefore, two portions of a circuit crossing each other tend to move until they are parallel, and their currents are flowing in the same direction.

(3) Successive portions of the circuit of the same *rectilineal current*, that is, a current flowing in the same straight line, repel one another.

Continuous Rotations by Currents.—A circuit O A, Fig. 173, movable on O, as a centre, will be continuously rotated in the direction of the curved arrow by the rectilinear current, P Q;

for, the directions of the currents being as shown by the arrows, there will be attraction in the positions (1) and (2), and repulsion in position (4).

The cause of the mutual attractions and repulsions of electric circuits will readily appear from a consideration of the mutual action of their magnetic fields.

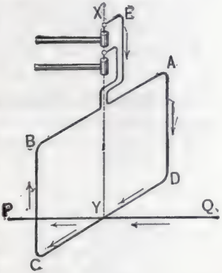


Fig. 172.

Thus an inspection of Fig. 174, shows:

(1) That parallel currents flowing in the same direction attract, *because their lines of force have opposite directions in adjoining parts of the circuit.*

(2) That parallel currents flowing in *opposite* directions *repel*, *because their lines of force have the same direction in adjoining parts of the circuit.*

These laws may therefore be generalized thus, viz.: *Lines of force extending in opposite directions attract one another; lines of force extending in the same direction repel one another.*

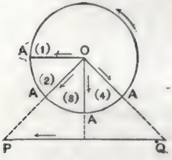


Fig. 173.

Ampère proved that a circuit, doubled on itself so that the current flows in opposite directions in the two parts, exerts no force on external objects. This expedient is adopted in resistance coils to prevent any disturbance of the galvanometer needles. He also showed that a *sinuous circuit*, or one bent into zigzags, produces the same effects of attraction or repulsion as it would if it were straight. (See *Coils, Resistance.*)

The term *sinuous current* is often applied to the current in such a conductor. (See *Currents, Sinuous.*)

Electro-Dynamometer.—(See *Dynamometer, Electric.*)

Electro-Etching.—(See *Engraving, Electric*).

Electrokinetics.—A term sometimes applied to the phenomena of electric currents, or electricity in motion, as distinguished from *Electrostatics*, the phenomena of electric charges, or electricity at rest.

Electrolier.—A chandelier for electric lights, as distinguished from a chandelier for holding gas lights.

Electrolysis, Faraday's Laws of ——— —The principal facts of electrolysis are given in the following laws :

(1) The amount of chemical action in any given time is equal in all parts of the circuit.

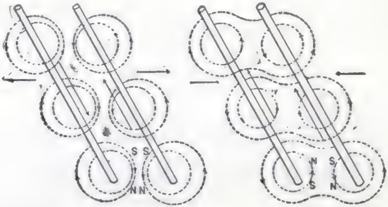


Fig. 174.

(2) The amount of any *ion* liberated in a given time, is proportional to the strength of the current passing. Twice as great a current will liberate twice as much of an *ion*.

(3) When the same current passes successively through several cells containing different electrolytes, the weights of the *ions* liberated at the different electrodes are equal to the strength of the current multiplied by the electro-chemical equivalent of the *ion*.

The *electro-chemical equivalent is equal to the atomic weight* divided by the *valency*. (See *Equivalent, Electro-Chemical.*)

Electrolysis, or Electrolytic Decomposition.—Chemical decompositions effected by means of the electric current.

When an electric current is sent through an *electrolyte*, i. e., a liquid which permits the current to pass only by means of the decomposition of the liquid, the decomposition that ensues is called *electrolytic decomposition.*

The electrolyte is decomposed or broken up into atoms or groups of atoms or *radicals*, called *ions.*

The *ions* are of two distinct kinds, viz.: the *electro-positive ions*, or *kathions* or *kations*, and the *electro-negative ions* or *anions.*

Since the *anode* of the source is connected with the electro-positive terminal, it is clear that the *anions*, or the *electro-negative ions*, must appear at the *anode*, and the *kathions*, or the *electro-positive ions*, must appear at the *kathode.*

Hydrogen, and the metals generally, are *kathions ;* oxygen, chlorine, iodine, etc., are *anions.*

The vessel containing the electrolyte, in which these decompositions take place, is called an *electrolytic cell.*

An electrolytic cell is called a *voltameter*, when it is arranged for measuring the current passing by means of the amount of decomposition it effects. (See *Voltameters.*)

Electrolytic Convection.—(See *Convection, Electrolytic.*)

Electro-Magnet.—A magnet produced by the passage of an electric current through a coil of insulated wire surrounding a core of magnetizable material.

The magnetizing coil is called a *helix* or *solenoid.* (See *Magnetism, Ampère's Theory of. Solenoid, Electro-Magnetic.*)

Strictly speaking, the term electro-magnet is limited to the case of a magnet provided with a soft iron core, which is thus enabled to rapidly acquire its magnetism on the passage of the magnetizing current, and as readily to lose its magnetism on the cessation of such current.

An electric current passed around a bar of magnetizable material, in the manner and direction shown in Fig. 175, will produce a polarity at its ends or extremities.

The direction of this polarity may be predicted by the following modifications of a rule proposed by Ampère:

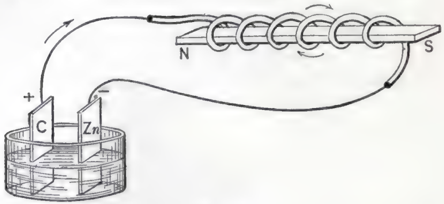


Fig. 175.

Imagine yourself swimming in the wire in the direction of the current; if, then your face is directed towards the bar that is being magnetized, its north seeking pole will be on your left.

If, for example, the conductor A B be traversed by a current in the direction from B to A, as shown in Fig. 177, the north pole N, of the needle N S, *placed under the conductor*, is deflected, as shown, to the left of the observer, who is supposed to be swimming in the current, facing the needle. If the current flow in the opposite direction, as from A to B, as shown in the Fig. 178, the N pole of the needle is deflected as shown, but still to the left of the observer supposed to be swimming as before.

The directions of currents required to produce N and S poles respectively, are shown in Fig. 176.

The cause of this direction of polarity will be readily understood from a study of the direction of lines of magnetic force in the field produced by an electric current.

In any electric circuit, the lines of magnetic force, produced by the passage of the current, form circles around the circuit in planes at right angles to the *direction of the current*, as shown in Fig. 179. The *direction of these lines of force is the same as that of the hands of a watch, if the current be supposed to flow away from the observer.* (See *Field, Magnetic, of an Electric Current.*)

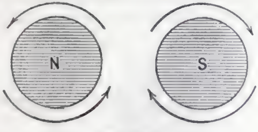


Fig. 176.

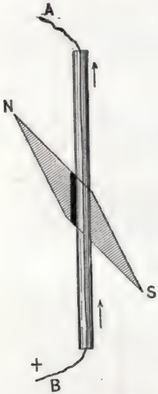


Fig. 178.

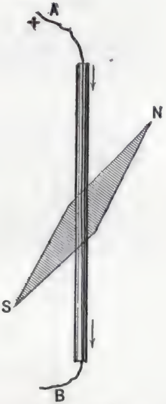


Fig. 177.

Remembering now that the lines of force are supposed to come *out of the north pole* and to pass into the south pole, it is evident that if the current flows in the direction shown in Fig. 180, the lines of force will come out of the north pole and pass into the south pole.

Since in a right handed helix the wire passes around the axis in the opposite direction to that in which it passes in a left handed helix, it is evident that the helices shown in Fig. 181 at 1 and 2, will produce opposite polarities at the points of entrance and exit by a current flowing in the direction of the arrows.

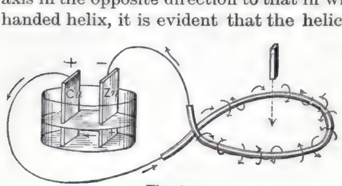


Fig. 179.

If the current be sent through the right handed helix, shown at 1, from b to a, that is, from the left to the right in the figure, a south pole will be produced at b, and a north pole at a. If, however, it be sent from a to b, the polarity will be reversed.

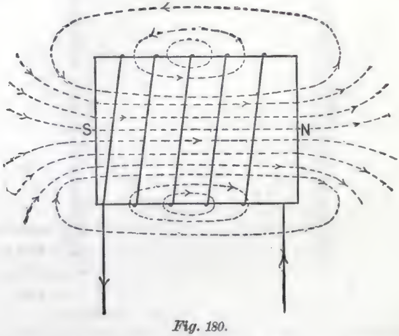


Fig. 180.

If the current be sent through the left handed helix, shown at 2, from a, to b, that is, from the left to the right in the figure, a north pole will be produced at a, and a south pole at b. If,

however, it be sent in the opposite direction the polarity will be reversed.

Therefore, in an electro magnet, on the core of which several layers or thicknesses of wire are wound, in which the current flows through one layer, in, say a direction from right to left, it must return through the next layer in the opposite direction, or from left to right. The polarities of the same extremities of the helices are, however, the same in all cases, *since the layers are successively right and left handed.* The winding at 3 produces a number of consequent poles.

Electro-Magnets, Laws of.

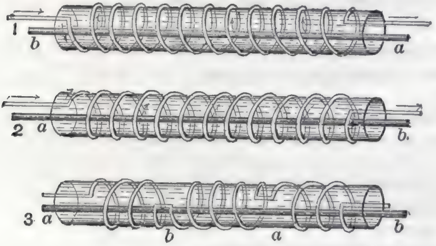


Fig. 181.

(1) The magnetic intensity (strength) of an electro magnet is nearly proportional to the strength of the magnetizing current, provided the core is not saturated.

(2) The magnetic strength is proportional to number of turns of wire in the magnetizing coil.

(3) The magnetic strength is independent of the thickness or material of the conducting wires.

These laws may be embraced in the more general statement that the strength of an electro magnet, the size of the magnet being the same, is 'proportional to the number of its *Ampère Turns.* (See *Ampère-Turns.*)

A short interval of time is required for a current to thoroughly magnetize a powerful electro-magnet.

A few moments are also required for a powerful magnet to thoroughly lose its magnetism. At the same time, electro magnets are capable of acquiring or losing their magnetism several thousand times a second. It is, in fact, on this ability possessed to so remarkable a degree by soft iron, that the value of an electro magnet for many purposes depends. (See *Lag, Magnetic.*)

Electro-Magnetic Annunciator.—(See *Annunciator, Electro-Magnetic.*)

Electro-Magnetic Dental Mallet.—(See *Dental Mallet, Electro-Magnetic.*)

Electro-Magnetic Drill.—(See *Drill, Electro-Magnetic.*)

Electro-Magnetic Engine.—(See *Engine, Electro-Magnetic.*)

Electro-Magnetic Induction.—A variety of electro-dynamic induction in which electric currents are produced by the motion of electro magnets, or electro-magnetic solenoids. (See *Induction, Electro-Dynamic.*)

Electro-Magnetic Solenoid.—(See *Solenoid, Electro-Magnetic.*)

Electro-Magnetic Stress ——— —The force or pressure in a magnetic field which produces a strain or deformation in a piece of glass or other similar substance placed therein. (See *Optical Strain, Electro-Magnetic.*)

Electro-Magnetics.—That branch of electric science which treats of the relations between electric currents and magnets.

Electro-Metallurgy.—Metallurgical processes effected by the agency of electricity.

Electro-Metallurgy embraces :

(1) The Reduction of Metals from their ores, either directly from their fusion by the heat of the voltaic arc, or the heat of

incandescence, or by the electrolysis of solutions of their ores. (See *Electrolysis. Furnace, Electric.*)

(2) Electroplating.

(3) Electrotyping.

The application of electricity to the reduction of metals is carried on in the electric furnace for the reduction of the aluminium ores.

Electrometer.—An apparatus for measuring differences of potential.

Electrometers, operate in general, by means of the attraction or repulsion of charged conductors on a suitably suspended needle or disc. As no current is required to flow through the apparatus it is adaptable to many cases where a voltmeter could not be so readily used.

Electrometer, Absolute ——— —A form of *attracted disc electrometer.* (See *Electrometer, Attracted Disc.*)

Electrometer, Attracted Disc ——— —A form of electrometer devised by Sir Wm. Thomson, in which the force is measured by the attraction between two discs.

Thomson's Attracted Disc Electrometer is shown in Fig. 182. It consists of a plate C, suspended from the longer end of a lever *l*, within the fixed *guard plate,* or *guard ring,* B, immediately above a second plate A, supported on an insulated stand, and capable of a measurable approach towards C, or a movement away from it. The plate C, is placed in contact with B, by means of a thin

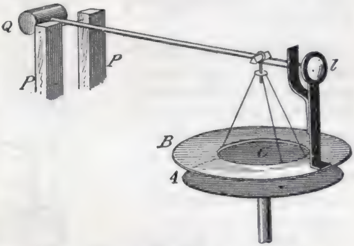


Fig. 182.

wire. By means of this connection the distribution of the charge over the plate C, is uniform. The electrostatic attraction is measured by the attraction of the fixed disc A, or the movable disc C. The fulcrum of the lever *l*, is formed of an aluminium wire, the torsion of which is used to measure the force of the attraction, or, it may be measured directly by the counterpoise weight Q.

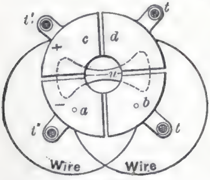


Fig. 183.

This instrument is called an absolute electrometer, because, knowing the dimensions of the apparatus, the value of the electro-motive force can be directly determined from the amount of the motion observed.

Electrometer, Capillary ——— —(See *Capillary Electrometer.*)

Electrometer, Quadrant ——— —An electrometer in which the electrostatic charge is measured by the attractive force of plates or quadrants, *a, b, c, d,* Fig. 183, on a light needle *u,* of aluminium suspended within them.

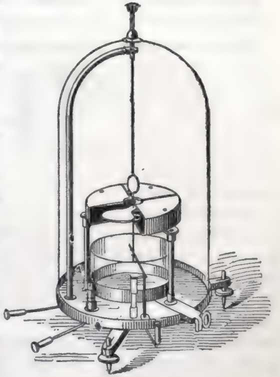


Fig. 184.

The sectors or quadrants are of brass, and are so shaped as to form a hollow cylindrical box when placed together. The four sectors or quadrants, are insulated from one another, but the opposite ones are connected by a conducting wire, as shown

in Fig. 183. A light needle of aluminium that is maintained at some constant potential, by connection with the inner coating of a Leyden jar, is generally suspended by two parallel silk threads, so that it freely swings inside the hollow box, and, when at rest, is in the position, as shown by the dotted lines, with its axis of symmetry exactly under one of the slots or spaces between the opposite sectors. (See *Bi-Filar Suspension.*)

The quadrant electrometer is shown in Fig. 184, with one of the quadrants removed so as to show the suspended aluminium needle.

A similar form of instrument is shown in Fig. 185, with all the quadrants in place, and covered by a glass shade.

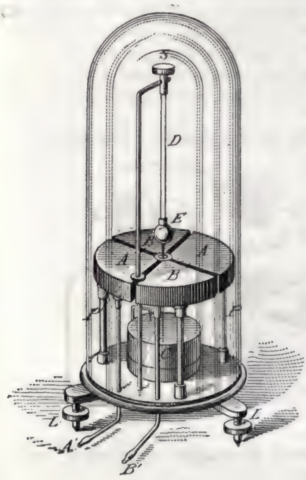


Fig. 185.

To use the instrument, the sectors are connected with the source whose difference of potential is to be measured, and the deflection of the needle observed, through a *telescope*, by means of a spot of light reflected from a mirror attached to the upper part of the needle.

Sometimes the segments are made in the shape of a cylinder, and the needle in the shape of a suspended rectangle.

Electro-Motive Force, or E. M. F.—The force that causes electricity to move.

The term electro-motive force is generally written thus: *E.M.F.*

The electro-motive force is due to a difference of electrical level or *potential.* In the current that results, the flow is assumed to be directed from the *higher* to the lower level, just as in the case of liquids. (See *Potential.*)

The term electro-motive force should not be used as entirely synonymous with *difference of potential.* The electro-motive force of any source is only correctly applied to the *total generated difference of potential.* Anything less than this at various parts of the circuit is more correctly spoken of as a *difference of potential.*

The unit of electro-motive force is the *volt.* (See *Volt.*)

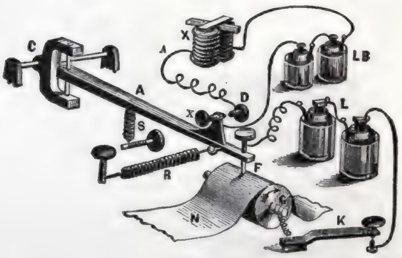


Fig. 186.

Electro-Motive Force, Average —— —(See *Average Electro-Motive Force.*)

Electro-Motive Force, Counter or Back —— —(See *Counter Electro-Motive Force.*)

Electro-Motograph.—An apparatus invented by Edison whereby the friction of a platinum point against a rotating cylinder of moist chalk is reduced by the passage of an electric current.

This result is due to an electrolytic action at the points of contact, varying the friction.

Edison has constructed a telephone on this principle. The electro-motograph, though less certain in its action than an electro-magnet, may replace it in certain electric apparatus.

The detailed construction of the electro-motograph may be understood from an inspection of Fig. 186.

The lever A, pivoted with a universal joint at C, has a metallic point at its free extremity F, resting on a strip of moistened paper N, and held against it with some pressure by the action of the spring S. The paper N rests on the metallic drum G, over which it is moved in the direction of the arrow on the rotation of the drum by clockwork. A spring R acts to move the lever A in a direction opposite to that in which it tends to move by the rotation of the drum G.

The main battery L is connected at its negative pole to the point F and at its positive pole, through the key K, to the metallic drum G. The local battery L B, is connected through the sounder X to the contacts D and X.

When the key K is open, the friction of F on the paper, N, is sufficient to move the lever A to the right so as to close the circuit of the local battery; but when the key K is depressed, the current of L, passing through the paper, decomposes the chemicals with which it is moistened, lessens the friction of the point F, and permits the spring B, to draw the lever A, to the left, thus opening the circuit of the local battery L B.

The movements of the key are therefore reproduced by the armature of the electro-magnet X.

Electro-Muscular Excitation.—In electro therapeutics the galvanic or faradic excitation of the muscle, or its excitation by the continuous currents of a voltaic battery, or the alternating currents of an induction coil.

Electro-Optics.—(See *Optics, Electro.*)

Electrophorus.—An apparatus for the production of electricity by *electrostatic induction.* (See *Induction, Electrostatic.*)

A disc of vulcanite, or hard rubber B, contained in a metallic form, is rubbed briskly by a piece of cat's skin and the insulated metallic disc A, is placed on the centre of the vulcanite disc, as shown in Fig. 187.

Fig. 187.

The negative charge produced in B by the friction, produces by induction a positive charge on the part of A nearest it, and a negative charge on the part furthest from it.

In this condition, if the disc be raised from the plate by means of its insulating handle, as shown in Fig. 188, no electrical effects will be noticed, since the two opposite and equal charges unite and neutralize each other. If, however, the disc A be first touched by the finger, and then raised from the disc B, it will be found to be *positively charged.*

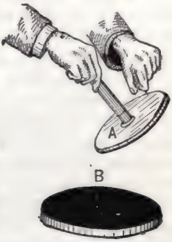


Fig. 188.

Electro-Physiology. — The study of the electric phenomena of living animals and plants.

Living animals and plants present electric phenomena, due to the electricity naturally produced by them. It is the study of electro-physiology to ascertain the causes and effects of these phenomena.

Electro-Plating.—The process of covering any electrically conducting surface with a metal by the aid of the electric current.

By the aid of electro-plating, the baser metals are covered with silver, nickel, or copper, or with any other metal, such as gold, or platinum,

The process of electro-plating is carried on as follows :

The object to be plated is connected with the negative terminal of a battery and placed in a solution of the metal with which it is to be plated, opposite a plate of that metal connected to the negative terminal of the battery. If, for example, the object is to be plated with copper it is placed in a solution of copper sulphate or blue vitriol, opposite a plate of copper. By this arrangement the object to be plated forms the kathode of the plating bath, and the plate of copper forms the anode.

On the passage of the current the copper sulphate ($Cu\,SO_4$) is decomposed, metallic copper being deposited in an adherent layer on the articles attached to the kathode, and the acid radical (SO_4) appearing at the anode, where it combines with one of the atoms of the copper plate. Since for every molecule of copper sulphate decomposed in the electrolyte, a new molecule of copper sulphate is thus formed, by the gradual solution of the copper anode, the strength of the solution in the bath is maintained as long as any of the copper plate remains at the anode, and the ordinary activity of the cell is not otherwise interfered with.

When any other metals such as gold, silver, or nickel, for example, are to be deposited, suitable solutions of their salts are placed in the bath, and plates of the same metal hung at the anode.

The character and coherence of the metallic coatings thus obtained depend on the nature and strength of the plating bath, and on the density of the current employed. The size and position of the anode, as compared with that of the objects to be plated, must therefore be carefully attended to, as well as the strength of the metallic solution and the current strength passing. (See *Density of Current.*)

Fig. 189. shows a bath arranged for silver-plating.

The anode consists of a plate of silver. The spoons, forks, etc., to be plated are immersed in a suitable silver solution and connected with the kathode.

The electrotyping process is employed for the production of electrotype plates. It was called by Jacobi, the *galvano-plastic* process. The term *electrotyping* is however more generally adopted.

Electro-Pneumatic Signals.—(See " *Signals,*" *Electro-Pneumatic.*)

Electropoion Liquid.—A battery liquid consisting of one pound of bichromate of potash dissolved in ten pounds of water, to which two and one-half pounds of commercial sulphuric acid have been gradually added.

This liquid is employed with the carbon-zinc cell or the bichromate of potash cell.

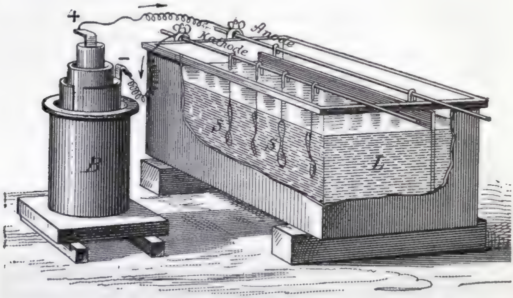


Fig. 189.

Electro-Puncture, or Galvano-Puncture.—The application of electrolysis to the treatment of aneurisms, or diseased growths.

The blood is decomposed by the introduction of a fine platinum needle connected with the anode of a battery and insulated, except near its point, by a covering of vulcanite.

The kathode is a sponge covered metallic plate.

Electro-Receptive Devices.—(See *Devices, Electro-Receptive.*)

Electroscope.—An apparatus for showing the presence of an electric charge, or for determining its sign, whether positive or negative, but not for measuring the value of the charge.

In the gold leaf electroscope, two gold leaves, *n n*, Fig. 190, suspended near one another, show by their repulsion the presence of a charge. Two pith balls may be used for the same purpose.

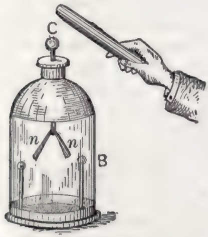


Fig. 190.

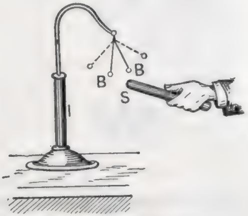


Fig. 191.

To use an electroscope for determining the *sign* of a charge, the gold leaves or pith balls are first slightly repelled by a charge of known name, as, for example, positive, applied to the knob C. They are then charged by the electrified body whose charge is to be determined. If they are further repelled, its charge is positive. If they are first attracted and afterwards repelled, its charge is negative.

Similarly, if the pith balls, B B, shown in Fig. 191, repelled by a known charge, be approached by a similar charge in S, they will at once be still further repelled, as shown by the dotted lines.

Two posts B, Fig. 190, connected with the earth, increase the amount of divergence by induction.

Electroscope, Condensing, ——— Volta's.—An electroscope employed for the detection of feeble charges, the leaves of which are charged by means of a condenser.

The condensing electroscope, Fig. 192, is formed of two metallic plates, placed at the top of the instrument, and separated by a suitable dielectric. The upper plate P, is removable by means of the insulated handle G.

Fig. 192.

To employ the electroscope, as for example, to detect the free charge in an unequally heated crystal of tourmaline the crystal is touched to the lower plate, while the upper plate is connected to the ground by the finger. On the subsequent removal of the upper plate, an enormous decrease ensues in the capacity of the condenser, and the charge now raises the potential of the lower plate, and causes a marked divergence of the leaves, L L. (See *Pyro-Electricity.*)

Electroscope, Quadrant ——— Henley's.—An electroscope sometimes employed to indicate large charges of electricity.

A pith ball placed on a light arm A, of straw or other similar material, Fig. 193, is pivoted at the centre of a graduated circle B. The arm C is attached by means of the screw to the prime conductor of an electric machine. The similar charge imparted to A by contact with C, causes a repulsion which may be measured on the graduated arc.

This instrument approaches the electrometer in its operation, since by its means simple measurements may be made of the value of the repulsion. It should not, however, be confounded with the *quadrant electrometer.* (See *Electrometer, Quadrant.*)

Electrostatic Field.—(See *Field, Electrostatic.*)

Electrostatic Induction.—(See *Induction, Electrostatic.*)

Electrostatic Induction Machines.—(See *Machines, Electrostatic Induction.*)

Electrostatic Lines of Force.—(See *Lines of Force, Electrostatic.*)

Electrostatic Stress.—The force, or pressure in an electric field which produces a strain or deformation in a piece of glass or similar body placed therein. (See *Optical Strain, Electrostatic.*)

Electrostatics.—That branch of electric science which treats of the phenomena and measurement of electric charges.

The principles of electrostatics are embraced in the following laws, viz.:

(1) Charges of like name, *i. e.*, either positive or negative, repel each other. Charges of unlike name attract each other.

(2) The forces of attraction, or repulsion between two charged bodies are directly proportional to the product of the quantities of electricity possessed by the bodies and inversely proportional to the square of the distance between them.

These laws can be demontsrated by the use of Coulomb's torsion balance. (See *Balance, Torsion.*)

Fig. 193.

Electro-Therapeutic Bath.—(See *Bath, Electro-Therapeutic.*)

Electro-Therapeutics, or Electro-Therapy.—The application of electricity to the curing of disease. (See *Electro-Biology*).

Electro-Therapy, or Electro-Therapeutics.—The application of electricity to the treatment of disease.

Electrotonus.—A condition of altered functional activity which occurs in a nerve when subjected to the action of an electric current.

This alteration may consist in either an increased or a decreased functional activity. The decreased functional activity occurs in the neighborhood of the anode or the positive terminal, and is called the *anelectrotonic state.* The increased functional activity occurs in the neighborhood of the kathode, or the negative terminal, and is called the *kathelectrotonic state.* (See *Anelectrotonous. Kathelectrotonous.*)

Electrotyping, or the Electrotype Process.—Obtaining casts or copies of objects by depositing metals in moulds by the agency of electric currents.

The moulds are made of wax, or other substance, rendered conducting by mixing with powdered plumbago.

The mould is connected with the negative battery terminal, and placed in a metallic solution, generally copper sulphate, opposite a plate of the same metal, connected with the positive battery terminal. As the current passes, the metal is deposited on the mould at the kathode, and dissolved from the metallic plate at the anode, thus maintaining constant the strength of the bath.

Element, Negative ——— —(See *Couple, Voltaic.*)

Element of Current.—(See *Current, Element of.*)

Element, or Elementary Matter.—Matter which cannot be decomposed into simple matter.

Matter that is formed or composed of but one kind of atoms.

Oxygen and hydrogen are elements, or varieties of elementary matter. They cannot be decomposed into anything but oxygen or hydrogen. Water, on the contrary, is *compound matter*, since it can be decomposed into its constituent parts, oxygen and hydrogen.

There are about seventy well known elements, some of which are very rare, occurring in extremely small quantities.

The evidence of the true elementary condition of many of the elements is based, to a great extent, on the fact that so far they have resisted all efforts made to decompose them into simpler substances. We should bear in mind, however, that until Davy's use of the voltaic battery, potash, soda and many other similar compounds were regarded as true elements. It is therefore not improbable that many of the now so-called elements, may hereafter be decomposed into simpler constituents.

Element, Positive ——— —(See *Couple, Voltaic.*)

The following tables give the names, chemical symbols, equivalents and specific gravities of the principal elements.

Simple Substances, with their Symbols, Equivalents and Specific Gravities.

Name.	Symbol.	Equiv.	Sp. Grav.
Aluminium	Al	13.7	2.56
Antimony	Sb	64.6	6.70
Arsenic	As	37.7	5.70
Bismuth	Bi	71.5	9.82
Bromine	Br	78.4	3.00
Cadmium	Cd	55.8	8.65
Calcium	Ca	20.5	1.58
Carbon	C	6.1	3.50
Chlorine	Cl	35.5	2.44
Cobalt	Co	29.5	8.53
Copper	Cu	31.7	8.80
Fluorine	F	18.7	1.32
Gold (aurum)	Au	196.6	19.30
Hydrogen	H	1.0	0.069
Iodine	I	126.5	4.94
Iridium	Ir	98.5	18.68
Iron	Fe	28.0	7.75
Lead	Pb	103.7	11.35
Magnesium	Mg	12.7	1.75
Manganese	Mn	26.0	8.00

NAME.	Symbol.	Equiv.	Sp. Grav.
Mercury	Hg	200.0	13.50
Molybdenum	Mo	47.9	8.60
Nickel	Ni	29.5	8.80
Nitrogen	N	14.2	0.972
Osmium	Os	99.7	10.00
Oxygen	O	8.0	1.102
Palladium	Pd	53.3	11.35
Phosphorus	P	15.9	1.77
Platinum	Pt	98.8	21.50
Potassium	K	39.2	0.865
Rhodium	R	52.2	11.00
Selenium	Se	40.0	4.5
Silver	Ag	108.3	10.5
Sodium	Na	23.5	0.972
Strontium	Sr	43.8	2.54
Sulphur	S	16.1	1.99
Tellurium	Te	64.2	6.30
Tin	Sn	58.9	7.29
Titanium	Ti	24.5	5.28
Tungsten	W	92.0	17.00
Uranium	U	60.0	10.15
Zinc	Zn	32.3	7.00

Clark & Sabine.

Element, Thermo-Electric ——— —One of the metals or substances which forms a *thermo-electric couple.* (See *Couple, Thermo-Electric.*)

Element, Voltaic ——— —One of the metals or substances which forms a *voltaic couple.* (See *Couple, Voltaic.*)

Elements, Electrical Classification of ——— —A classification of the elements into two groups or classes according to whether they appear at the anode or kathode when electrolyzed.

The chemical elements may be arranged into electro-positive and electro-negative according to whether, during electrolysis, they appear at the negative or positive terminal of the source.

The electro-positive elements or radicals are called ***kathions,***

and appear at the kathode or electro-negative terminal. The electro-negative elements are called *anions*, and appear at the anode or the electro-positive terminal. (See *Ions.*)

The metals generally are electro-positive; oxygen, chlorine, iodine, fluorine, etc., are electro-negative.

Elongation, Magnetic —— —An increase in the length of a bar of iron on its magnetization.

This increase in length is thought to greatly strengthen Hughes' theory of magnetism. (See *Magnetism, Hughes' Theory of.*)

Embosser, Telegraphic ——— —An apparatus for recording a telegraphic message in raised or embossed characters.

E. M. F.—A contraction generally used for the word electro-motive force.

Energy.—The power of doing work.

The amount of work done is measured by the product of the *force*, and the *space* through which it moves. Thus one pound raised vertically through ten feet, ten pounds raised through one foot, or five pounds raised through two feet, all represent the same amount of work, viz., ten *foot pounds.*

If a weight of ten pounds be raised through a vertical height of one foot, by means of a string passing over a pulley, there will have been expended an amount of energy represented by the work of ten foot pounds. If the weight be prevented in any way from falling, as by tying the string, it will have stored in it an amount of energy equal to ten foot pounds, and if permitted to fall, is capable of doing an amount of work which, leaving out air resistance and friction, is exactly equal to that expended in raising it to the position from which it falls, viz., ten foot pounds of work.

Energy, Actual, —— Kinetic Energy, Energy of Motion.—Energy employed in doing work, or the power of doing work possessed by bodies that are in motion.

Energy, Atomic or Chemical Potential ———The potential energy possessed by the elementary chemical atoms. (See *Energy, Potential.*)

Energy, Conservation of —— —(See *Conservation of Energy.*)

Energy, Degradation of ———(See *Degradation of Energy.*)

Energy, Electric ———The power which electricity possesses of doing work.

In the case of a liquid surface at different levels, the liquid at the higher level possesses a certain amount of *potential energy* measured by the *quantity* of the liquid at the higher level, and the excess of its height over that of the lower level; or, on the difference of level between them. This difference of level will produce a current *from the higher to the lower level,* and during the passage of the current, potential energy will be lost, and a certain amount of work will be done.

In the case of electricity, the *difference of electric level* or *potential,* between any two points of a conductor, causes an electric current to flow between these points from the higher to the lower electric level, during which *electric potential energy* is lost, and *work* is accomplished by the current. (See *Potential.*)

The amount of thc electric work is measured by the *quantity of electricity* that flows, multiplied by the *difference of potential* under which it flows. (See *Joule,* or *Volt-Coulomb.*)

Electric energy, however, is generally measured in *electric power,* or *rate of doing electric work.*

Since an *ampère* is one *coulomb per second,* if we measure the difference of potential in *volts,* the product of the ampères by the volts will give the electrical power in *volt-ampères,* or *watts,* or *units of electric power.* C E = The *Watts.* (See *Ampère. Volt. Watt.*)

One *horse-power* equals 550 foot pounds per second. One

watt or volt-ampère = $\frac{1}{746}$ of a horse-power, or one *horse-power* equals 746 *volt-ampères* or *watts*, therefore :

The current in ampères, multiplied by the difference of potential in volts, divided by 746, equals the rate of doing work in *horse-power.*

Thus, if .7 ampère is required to operate a 16 candle, 110 volt, incandescent lamp, it requires 4.8 *watts* per candle.

One Watt = 44.2394 foot-pounds per minute.

One Watt = .737324 foot-pounds per second.

The *Heat Activity*, or the heat per second produced by an electric current, is also proportional to the product C E, or the watts, for the heat is proportional to the *square* of the current in *ampères multiplied* by the *resistance* in ohms, or $C^2 R$ = the Heat. (See *Calorimeter, Electric.*)

By *Ohm's Law* (See *Ohm's Law*),

$$C = \frac{E}{R} \quad (1), \quad \text{or } C R = E \ , \quad (2),$$

but the electric power or the watts = C E (3).

If, now, we substitute the value of E, taken from equation (2) in equation (3) we have

$$C E = C \times C R = C^2 R;$$

therefore $C^2 R$ = watts.

To determine the heating power of a current in *small calories*, calling H, the amount of heat required to raise 1 *gramme* of water through 1° Cent., and C, the current in ampères.

$$H = C^2 R \times .24.$$

Or, for any number of seconds, *t*,

$$H = C^2 Rt \times .24,$$

Therefore, one watt = .24 calories per second. (See *Calorie.*)

But from *Ohm's law*,

$$C = \frac{E}{R} \qquad (1),$$

and the formula for electric power or the watts = C E . (2)

By substituting in equation (2) and the value of C in equation (1),

$$C\,E = E \times \frac{E}{R} = \frac{E^2}{R} = \text{watts.}$$

That is to say, the electric power, in any part of a circuit varies directly as the *square* of the *electro-motive force.*

We therefore have three expressions for the value of the watt or *the unit of electric power*, viz.:

$$C\,E = \text{watts.} \qquad (1)$$

$$C^2\,R = \text{watts.} \qquad (2)$$

$$\frac{E^2}{R} = \text{watts.} \qquad (3)$$

(1) C E = Watts; or the electric power is proportional to the product of the *quantity of electricity per second,* that passes, in *amperes,* and the *difference of electric potential or level,* through which it passes, in volts.

(2) C^2 R = Watts; or the electric power varies *directly* as the *resistance* R, *when the current is constant,* or as the *square of the current,* if the *resistance* is constant. That is to say, if with a given resistance, the power of a given current has a certain value, and the current flowing through this same resistance be *doubled,* the power is *four times* as *great,* or is as the square of the current.

(3) $\frac{E^2}{R}$ = Watts, or the electric power is *inversely* as the *resistance* R, *when the electro-motive force is constant.*

A circuit of one ohm resistance will have a power of *one* watt, when under an electric motive force of *one volt,* since it would then have a current of *one ampère* flowing through it, and C E = 1. If, however, the resistance be halved or becomes .5 ohm, then two ampères pass, or the power equals 2 watts.

The power varies as the *square of the electro-motive force* in any part of a circuit, *when the resistance is constant* in

that part. Thus 2 ampères, and 2 volts, in a circuit of one ohm resistance, give a power, $C E = 2 \times 2 = 4$ watts. If now, R, remaining the same, the electro-motive force be raised to 4 volts, then since E is doubled, C, or the ampères are doubled,

and $C \times E = 4 \times 4 = 16$ watts, or $\frac{E^2}{R} = \frac{16}{1} = 16$.

Energy, Electric Transmission of ——— —The transmission of mechanical energy between two distant points connected by an electric conductor, by converting the mechanical energy into electrical energy at one point, sending the current so produced through the conductor, and reconverting the electrical into mechanical energy at the other point.

A system for the electric transmission of energy embraces:

(1) *A Conducting Circuit* between two stations.

(2) *An Electric Source,* or battery of electric sources, or machines, at one of the stations, generally in the form of a dynamo-electric machine, for converting mechanical energy into electric energy.

(3) *Electro-Receptive Devices,* generally *electric motors,* at the other station for reconverting the electric into mechanical energy. (See *Motors, Electro-Magnetic.*)

Energy, Potential, —— Energy of Position, Static Energy, or Energy of Stress.—Stored energy; potency or capability of doing work.

The capacity for doing work possessed by a body at rest, arising from its position as regards the earth, or from the position of its atoms as regards other atoms.

A pound of coal if raised vertically one foot, possesses, as a mere weight, an amount of energy capable of doing an amount of work equal to one foot pound. The atoms of carbon, however, of which it is composed, have been *raised* or *separated from those of oxygen,* or some other elementary substance, and when the coal is burned, or the carbon atoms fall towards

the oxygen atoms (*i. e.*, unite with them), the coal gives up the potential energy of its atoms in the form of heat.

All elementary substances possess in the same way *atomic*, or *chemical potential energy*, or the energy with which they tend to fall together. This energy varies in amount in different elements and becomes kinetic, as heat, on combination with other elements.

Engine, Electro-Magnetic ——— —A motor whose driving power is electricity. (See *Motor, Electric.*)

Engraving, Acoustic ——— —Engraving by the human voice.

In the *Phonograph*, *Graphophone*, and *Gramophone*, a diaphragm is set in vibration by the speaker's voice so that it cuts or engraves a record of its to-and-fro movements on a sheet of tin foil, on a cylinder of hardened wax, or on a specially coated plate of metal or glass. This record is employed in order to *reproduce the speech.* (See *Phonograph.*)

Engraving, Electric ——— or Electro-Etching. —A method for electrically *etching* or *engraving* a metallic plate by covering it with wax, tracing the design on the wax so as to expose the metal, connecting it with the *positive terminal* of a battery, and placing it in a bath opposite another plate of metal.

By the action of *electrolysis* the metal is dissolved from the exposed portions and deposited on the plate connected with the other terminal of the battery. (See *Electrolysis.*)

By connecting the waxed plate to the negative terminal, the metal will be deposited on the exposed portions, thus producing the design *in relief.* This latter method is not, however, apt to produce a sufficiently uniform deposit to enable the plate so formed to be used for printing from.

Entropy.—In thermo-dynamics the non-available energy in any system. (*Clausius and Mayer.*)

The available energy in any system. (*Tait, Thomson, and Maxwell.*)

As will be noticed this term is used in entirely different and opposite senses by different scientific men. The latter sense is, perhaps, the one most generally taken.

Heat energy is available for doing useful external work only when the source of heat is hotter than surrounding bodies, that is, when the heat is transferred from a hotter to a colder body. When all bodies acquire the same temperature no more external work can be done by them. In the various transformations of energy some of the energy is converted into heat, and this heat is gradually diffused through the universe and thus becomes non-available to man. Therefore, the entropy of our earth is decreasing.

"Entropy, in Thermodynamics," says Maxwell, "is a quantity relating to a body such that its increase or diminution implies that heat has entered or left the body. The amount of heat which enters or leaves the body is measured by the product of the increase or diminution of entropy into the temperature at which it takes place."

Entropy, Electric —— —A term proposed by Maxwell in thermo-electric phenomena to include the doctrine of entropy in electric science.

"When an electric current," says Maxwell, "passes from one metal to another heat is emitted or absorbed at the junction of the metals. We should, therefore, suppose that the electric entropy has diminished or increased when the electricity passes from one metal to the other, the electric entropy being different according to the nature of the medium in which the electricity is, and being affected by its temperature, stress, strain, etc."

Equator, Geographical ——— —An imaginary great circle passing around the earth midway between its poles.

Equator, Magnetic —— —The magnetic parallel, or circle on the earth's surface where a magnetic needle free to more stands horizontal.

An irregular line passing around the earth approximately midway between the earth's magnetic poles. (See *Dip, Angle of.*)

Equator of Magnet.—A point midway between the poles of a bar magnet.

This term was proposed by Dr. Gilbert. It is now almost entirely displaced by the term *neutral point* or *points.*

Equipotential Surfaces.—Surfaces, all the points of which are at the same electric potential. (See *Potential, Electric.*)

Electric surfaces perpendicular to the lines of *electric force* over which a quantity of electricity, considered as being concentrated at a point, may be moved without doing work. (See *Field, Electrostatic.*)

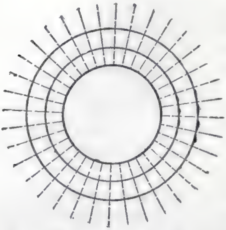


Fig. 194.

In electrostatics, equipotential surfaces correspond with a water level, over which a body may be moved horizontally against the force of gravity without doing any work.

In the case of the charged insulated sphere, shown in the Fig. 194, the equipotential surfaces, represented by the circles, are concentric.

Equipotential Surfaces, Magnetic —— —— —
Surfaces surrounding the poles of a magnet, or system of magnets, where the magnetic potential is the same. (See *Potential, Magnetic.*)

Magnetic equipotential surfaces extend in a direction perpendicular to the lines of magnetic force. (See *Field, Magnetic.*)

Therefore work is required in order to move a unit pole

across equipotential magnetic surfaces, because in so doing it cuts the lines of magnetic force.

Equipotential surfaces, whether electric or magnetic, cannot intersect one another since their potential is the same at all points.

Equivalent, Chemical ——— —The quotient obtained by dividing the *atomic weight* of any elementary substance by its *atomicity*. (See *Atomic Weight. Atomicity.*)

The chemical equivalent is different from the atomic weight. The atomic weight of gold is 196.6, but since in chemical combination one atom of gold is capable of combining with three atoms of hydrogen, the weight of the gold, equivalent to that of one atom of hydrogen is one-third of 196.6, or 65.5.

Equivalent, Electro-Chemical.—A number representing the weight of an elementary substance liberated during *electrolysis* by the passage of one *coulomb* of electricity. (See *Electrolysis. Coulomb.*)

It may be determined experimentally that one coulomb of electricity expended electrolytically will liberate .0000105 grammes of hydrogen. Therefore a current of one *ampère*, or *one coulomb per second*, will liberate .0000105 gramme of hydrogen per second. The number .0000105 is the electro-chemical equivalent of hydrogen.

The electro-chemical equivalents of the other elements are obtained by multiplying the electro-chemical equivalent of hydrogen by the chemical equivalent of the substance.

Thus, the chemical equivalent of potassium is 39.1, therefore its electro-chemical equivalent is $39.1 \times .0000105 = .00041055$. By multiplying the strength of the current that passes by the electro-chemical equivalent of any substance, we obtain the weight of that substance liberated by electrolysis.

The following Table of Electro-Chemical Equivalents is collected from different authorities, mainly Hospitalier.

Electro-Chemical Equivalents.

Names of Elements.	Atomic Weight.	Valency.	Chemical Equivalent.	Electro-chemical equivalents in grammes per Coulomb.	Number of Coulombs necessary to liberate one gramme.	Mass liberated per hour by currents of one Ampère.
Electro-positive.						
Hydrogen	1.	1	1.	.0000105	96,000	.0378
Potassium	39.1	1	39.1	.0004105	2,455	1.4680
Sodium	23.	1	23.	.0002415	4,174	.8694
Gold	196.6	3	65.5	.0006875	1,466	2.4750
Silver	108.	1	108.	.0011340	889	4.0824
Copper (ic salts)	63.	2	31.5	0003307	3,079	1.1900
Copper (ous salts)	63.	1	63.	.0006615	1,540	2.3800
Mercury (ic salts)	200.	2	100.	.0010500	960	3.7800
Mercury (ous salts)	200.	1	200.	0021000	480	7.5600
Tin (ic salts)	118.	4	29.5	.0003097	3,254	1.1149
Tin (ous salts)	118.	2	59.	.0006195	1,627	2.2298
Iron (ic salts)	56.	4	14.	.0001470	6,857	.5292
Iron (ous salts)	56.	2	28.	.0002940	3,429	1.0584
Nickel	59.	2	29.5	0003097	3,254	1.1249
Zinc	65.	2	32.5	0003412	2,953	1.2283
Lead	207.	2	103.5	.0010867	928	3.9041
Electro-negative.						
Oxygen	16.	2	8.	.0000840	----	------
Chlorine	35.5	1	35.5	.0003727	----	------
Iodine	127.	1	127.	.0013335	----	------
Bromine	80	1	80.	.0008400	----	------
Nitrogen	14.	3	4.3	.0000490	----	------

Equivalent of Heat, Mechanical ——— —(See *Mechanical Equivalent of Heat.*)

Equivolt.—A term proposed by J. T. Sprague for the unit of electrical energy, applied especially to chemical decomposition.

Sprague defines equivolt as follows : "The mechanical energy of one volt electro-motive force exerted under unit conditions through one equivalent of chemical action in grains."

This term has not been generally accepted. (See *Volt-Coulomb*, or *Joule.*)

Erg.—The unit of work, or the work done when unit force is overcome through unit distance.

The work accomplished when a body is moved through a distance of one centimetre with the force of one *dyne.* (See *Dyne.*)

The work done when a weight of one gramme is raised against gravity through a vertical height of one centimetre, is equal to 981 ergs, because the weight of one gramme is 1×981 dynes, or 981 ergs.

The dyne is the unit of force, or a force capable, after acting for one second, of giving a mass of one gramme a velocity of one centimetre per second. The *weight* of a body in *dynes*, or the force with which it gravitates, is equal to its mass in grammes, multiplied by the acceleration imparted to it in centimetres per second. For this latitude the acceleration is about 981 centimetres per second.

Ergmeter.—An apparatus for measuring in *ergs* the work of an electric current.

Erg-ten.—A term proposed for ten million ergs or $1 \times 10^{10} = 10{,}000{,}000{,}000$.

In representing large numbers containing many ciphers the plan is often adopted of representing the number of ciphers that are to be added to a given number by 10, with an exponent equal to the number of ciphers. Thus, 38×10^8 indicates that 38 is to be followed by 8 ciphers, thus 3,800,000,000.

A negative exponent, as 3×10^{-8} represents the corresponding decimal thus, .00,000,003.

1 erg $\times 10^{10}$, or 10,000,000,000 is called an erg-*ten.* 1×10^6

= an erg-*six*. These terms are not in general use. Ten meg-ergs is a preferable phrase to an erg-ten. (See *Meg-erg.*)

Escape, Electric ——— — A term sometimes employed to indicate the loss of charge on an insulated conductor. (See *Leakage, Electric.*)

Etching, Electric ——— — (See *Engraving, Electric.*)

Ether.—The tenuous, highly elastic fluid that is assumed to fill all space, and by vibrations or waves in which light and heat are transmitted.

Although the existence of the ether is assumed in order to explain certain phenomena, its actual existence is very generally credited by scientific men, and, in reality, proofs are not wanting to fairly establish its existence.

Light and heat are believed to be due to transverse vibrations in the ether. Magnetism appears to be due to whirls or whirl-pools, and an electric current is believed by some to be due to ether set in motion by differences in the ether pressures.

It is not correct to regard the luminiferous ether as possessing no weight, or as being imponderable. Maxwell estimates its density as $\frac{936}{1,000,000,000,000,000,000,000}$ that of water. It is very readily moved or set into vibration, its rigidity being estimated at about $\frac{1}{1,000,000,000}$ that of steel.

According to the speculations of some physicists the ether is not discontinuous or granular, but is similar to what might be regarded as an almost impalpable jelly.

Eudiometer.—A *Voltameter* in which separate graduated vessels are provided for the reception and measurement of the gaseous products evolved during electrolysis. (See *Voltameter.*)

In all cases electrodes must be used which do not enter into combination with the evolved gaseous products. In the case of oxygen and hydrogen, platinum is generally used.

A form of eudiometer is shown in Fig. 195. Two separate glass vessels provided at the top with stop cocks, and open at their lower ends, rest in a vessel of water A, over platinum electrodes, connected electrically with binding posts K, K. Both vessels are filled with water slightly acidulated with sulphuric acid, and, when connected with a battery of sufficient electro-motive force, (not less than 1.45 volts), electrolysis takes place, and hydrogen gas collects in the vessel over the platinum electrode connected with the negative battery terminal, and oxygen in that over the one connected with the positive battery terminal. The volume of the hydrogen is about twice as great as that of the oxygen. (See *Water, Electrolysis of.*)

Fig. 195.

Evaporation.—The change from the liquid to the vaporous state.

Wet clothes exposed to the air are dried by the evaporation of the water.

Evaporation is greater :

(1) The more extended the surface exposed.

(2) The higher the temperature of the air.

(3) The dryer the air, or the smaller the quantity of vapor already in it.

(4) The stronger the wind.

(5) The smaller the pressure of the air.

Evaporation, Electrification by ————Electrification resulting from the condensation of a mass of vapor.

The free electricity of the atmosphere is believed by some to be due to the condensation of the vapor of the air that results in rain, hail, clouds, etc. It is probable, however, that the true effect of condensation is mainly limited to the increase of a feeble electrification already possessed by the air or its contained vapor. The small difference of potential of the exceedingly small drops of water in clouds, is enormously increased by the union or coalescing of many thousands of such drops into a single rain drop. (See *Atmospheric Electricity.*)

Exchange, Telephonic ——— System of—A combination of circuits, switches and other devices, by means of which any one of a number of subscribers connected with a telephonic circuit, or a neighboring telephonic circuit or circuits, may be placed in electrical communication with any other subscriber connected with such circuit or circuits.

A telephone exchange consists essentially of a multiple switch-board, or a number of multiple switch-boards, furnished with *spring-jacks, annunciator drops,* and suitable *connecting cords.* A *call bell,* or bells, is also provided. The annunciator drops are often omitted. (See *Board, Multiple Switch.*)

Excitability, Electric ——— of Nerve or Muscular Fibre.—The effect produced by an electric current in stimulating the nerve of a living animal or producing an involuntary contraction of a muscle.

Du Bois-Reymond has shown that these effects depend ;

(1) On the strength of the current employed, and that they occur only when the current begins to flow, and when it ceases flowing, or, when the electrodes first touch the nerves, and when they are separated from it. Subsequent investigation have shown that this is true only for the frog's nerves,

and is true for the human nerves only in the case of moderate currents, strong currents producing tetanus.

(2) On the rapidity with which the current used reaches its maximum value, that is, on the rapidity of change of *current density*. (See *Current Density*.)

Excitability, Faradic ——— —*Muscular* or *nervous excitability* following the employment of the rapidly intermittent current produced by *induction coils*. (See *Induction Coils*.)

Faradic excitability is different from *galvanic excitability*, produced by means of a continuous voltaic current.

Excitation, Electro Muscular ——— — (See *Electro Muscular Excitation*.)

Exciter of Field.—In a separately excited *dynamo-electric machine*, the dynamo-electric machine, voltaic battery, or other electric source employed to produce the field of the field magnets. (See *Dynamo-Electric Machines*.)

Execution, Electric ——— —Causing the death of a criminal, in cases of capital punishment, by means of the electric current.

Electric execution has been adopted by the State of New York, in accordance with the following law:

"The Court shall sentence the prisoner to death within a certain week, naming no day or hour, and not more than eight nor less than five weeks from the day of sentence. The execution must take place in the State prison to which convicted felons are sent by the court, and the executioner must be the agent and warden of the prison."

"No newspaper may print any details of the execution, which is to be inflicted by electricity. A current of electricity is to be caused to pass through the body of the condemned of sufficient intensity to kill him, and the application is to be continued until he is dead."

Exhaustion, or Prostration ——— Electric.—(See *Sun Stroke, Electric*.)

Exhaustion of Voltaic Cell.—The condition of a voltaic cell in which, on account of having all its active electrolyte decomposed, or its positive plate dissolved, it will furnish no difference of potential and therefore no current.

An exhausted secondary cell is revivified or charged, by the passage through it of a charging current.

A primary cell is revivified by the addition of fresh electrolyte or battery liquid, or a new positive plate.

Expansion, Electric ———— — The increase in volume produced in a body on giving such body an electric *charge.*

A Leyden jar increases in volume when a charge is imparted to it. This result is due to an expansion of the glass due to the electric charge. According to Quincke, some substances, such as resinous or oily bodies, manifest a *contraction of volume* on the reception of an electric charge.

Expansion Joints.—(See *Joints, Expansion.*)

Exploder, Electric ———— — A small magneto-electric machine used to produce the currents of high electro-mo-tive force, employed in the direct firing of blasts.

Explorer, Electric ———— — An apparatus operated by means of induced currents, and employed for the purpose of locating bullets or other foreign metallic substances in the human body. (See *Balance, Induction, Hughes.*)

Explorer, Magnetic ———— — A small, flat coil of insulated wire, used in the circuit of a telephone to determine the position and extent of the magnetic leakage of a dynamo-electric machine or other similar apparatus. (See *Magneto-phone.*)

Extension Call-Bell.—(See *Bell, Extension Call.*)

Extra Currents.—Currents produced in a circuit, by the induction of the current on itself, on the *opening* or *closing* of a circuit. (See *Currents, Extra.*)

Eye, Selenium ———— —(See *Selenium Eye.*)

Fac-Simile Telegraphy, or Pantelegraphy.—The telegraphic transmission of fac-simile copies of drawings or designs.

In a system of fac-simile telegraphy, a design placed at one end of a telegraphic line is automatically reproduced by electricity at the other end of the line. (See *Telegraphy, Fac-simile.*)

Farad.—The unit of electric capacity.

As in gases, a quart vessel will hold a quart of gas under unit pressure of one atmosphere, so, in electricity, a conductor or *condenser*, whose capacity is one farad, will hold a quantity of electricity equal to one *coulomb*, when under an electro-motive force of one volt.

It may cause some perplexity to the student to understand why there should be in electricity *one unit of capacity* to represent the *size* of the vessel or conductor, and another to represent the *amount* or quantity of electricity required to fill such vessel. But, like a gas, electricity acts as if it were very compressible, so that the quantity required to fill any condenser will depend on the electro-motive force under which it is put into the conductor or condenser.

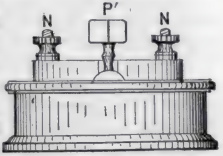


Fig. 196.

A farad is such a capacity of a conductor or condenser that one coulomb of electricity is required to produce in it a difference of potential of one volt.

For purposes of measurement, capacities of conductors are compared with those of condensers whose capacities are known in microfarads, or fractions thereof. The microfarad, or the $\frac{1}{1,000,000}$ of a farad, is used because of the very great size of a farad.

Fig. 196, shows an elevation and Fig. 197 a plan of the form

often given to a standardized condenser or microfarad. The condenser is charged by connecting the terminals of the electric source to the binding posts N and N. It is discharged by means of the plug key P′, that connects the brass pieces A and B, when pushed firmly into the conical space between them.

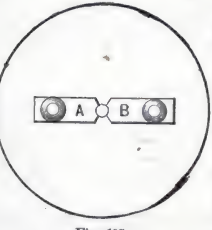


Fig. 197.

The condenser is made by placing sheets of tin foil between sheets of oiled silk or mica in the box, and connecting the alternate sheets to one of the brass pieces B, and the other set to the piece A, as will be better understood from an inspection of Fig. 198. A condenser of a microfarad capacity will contain about 3,600 square inches of tin foil.

Condensers are generally made of the capacity of the $\frac{1}{3}$ of a *microfarad*. Sometimes, however, they are made so that either all or part of the condenser may be employed, by the insertion of the different plug keys.

The form of condenser, shown in Fig. 199 is capable of ready division into five different values, viz.: .05, .05, .2, .2, and .5 microfarad.

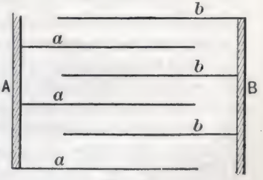


Fig. 198.

Faradic Apparatus, Magneto ——— — A small magneto-electric machine employed in electro therapeutics for producing faradic currents.

These machines consist essentially of a coil of wire wrapped on an armature core rotated before the poles of permanent magnets. No commutator is employed, since it is desired to obtain rapidly alternating currents.

Faradic Brush.—(See *Brush, Faradic.*)

Faradic Current.—In electro therapeutics the current produced by an induction coil.

A rapidly alternating current, as distinguished from a uniform voltaic current.

A voltaic current that is rapidly alternated by means of any suitable key or switch is sometimes called a *voltaic alternative.* The discharge from a Holtz machine is sometimes called a *Franklinic Current.*

Faradic Induction Apparatus.—An *induction coil* apparatus for producing faradic currents.

A voltaic battery is connected with the primary of an induction coil, and its current rapidly broken by an *automatic break,* or by a hand break. The alternating or faradic currents thus produced in the secondary coils are used for electro therapeutic purposes. (See *Induction Coil.*)

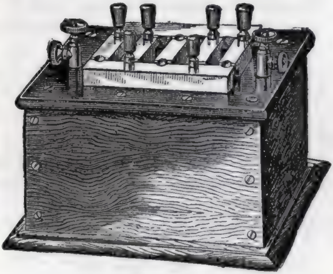


Fig. 199.

Faradic induction apparatus are made in a great variety of forms. They all operate, however, on essentially the same principles.

Faradic Machines.—Machines for producing Faradic currents.

These are of two varieties, viz.: *magneto-faradic* apparatus, and *simple induction* apparatus.

Faradization.—In electro therapeutics, the effects pro-

duced on the nerves or muscles by the use of a faradic current, in order to distinguish such effects from *galvanization* or those produced by a voltaic current.

Fahrenheit's Thermometer Scale.—A thermometer scale in which the length of the thermometer tube between the melting point of ice and the boiling point of water is divided into 180 equal parts called degrees.

On Fahrenheit's scale, water freezes at 32° F. and boils at 212° F. Degrees of this thermo-metric scale are represented by an F. (See *Centigrade Thermometer Scale.*)

False Pole, Magnetic ——— — A term proposed by Mascart and Joubert, to designate the extra magnetic poles of the earth, or places acting as magnetic poles, in addition to the two poles near the earth's geographical poles.

According to these authorities, the earth possesses two magnetic poles only, viz., a *negative pole* in the Northern Hemisphere, and a *positive pole* in the Southern Hemisphere. The additional poles, are called by them the *false magnetic poles.*

Faults.—Accidential leaks in a circuit caused by *ground contacts* or *crosses.* (See *Cross Contacts.*)

Faults are of three kinds, viz. :

(1) Disconnections. (See *Disconnections.*)

(2) Earths. (See *Earths.*)

(3) Contacts. (See *Contacts.*)

Various methods are employed for *detecting* and localizing faults, for the explanation of which reference should be had to standard electrical works.

Faults, Localization of ——— —(See *Localization of Faults.*)

Ferro-Magnetic Substances.—A term proposed in place of paramagnetic, for substances that are magnetic, after the manner of iron. (See *Paramagnetic.*)

Paramagnetic is the preferable term. The use of the term *ferro-magnetic* is both unnecessary and unwarranted.

Fibre-Suspension.—The suspension of a needle by means of a fibre.

Fibre suspension may be effected by means of a single fibre or thread, or by two parallel threads, which is called *bi-filar suspension.* (See *Suspension, Fibre. Suspension, Bi-filar.*)

Fibre, Vulcanized ——— —(See *Vulcanized Fibre.*)

Field, Electrostatic ——— —The region of electrostatic influence surrounding a charged body.

Electrostatic attractions or repulsions take place along certain lines called *lines of electrostatic force.* These lines of force produce a field called an *electrostatic* field. *Electric level* or *potential* is measured along these lines, just as gravitation levels are measured with a plumb line along the lines of gravitation force. (See *Potential.*)

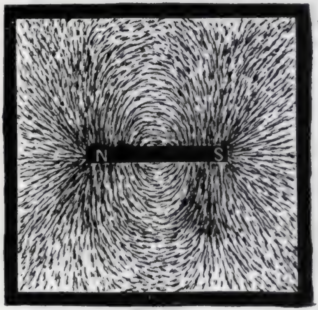


Fig. 200.

Work is done when a body is moved along the lines of electrostatic force in a direction *from* an oppositely charged body, or *towards* a similarly charged body, just as work is done against gravity, when a body is moved along the lines of gravitation force, away from the earth's centre, or vertically upwards.

Field, Intensity of———(See *Field, Magnetic. Field, Electrostatic. Field, Electro Magnetic.*)

Field, Magnetic ———The region of magnetic influence surrounding the poles of a magnet.

Strictly speaking a magnetic field is a place where a magnetic needle, if free to move, will take up a definite position.

Magnetic attractions and repulsions are assumed to take place along certain lines called *lines of magnetic force.* Their direction in any plane of a magnetic field, may be shown by sprinkling iron filings over a sheet of paper held in a horizontal position to a magnet pole inclined to the paper in the desired plane and then gently tapping the paper.

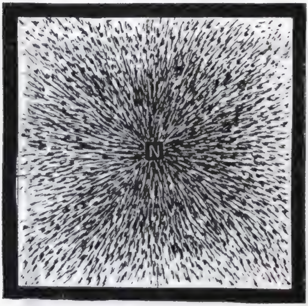


Fig. 201.

These are sometimes called *magnetic figures.*

The lines of force thus shown will appear from an inspection of Fig.200, taken in a plane joining the two poles of a straight bar magnet, and Fig. 201, taken in a plane at right angles to the north pole of a straight bar magnet.

In Fig. 200, the repulsion of the lines of force at either pole is shown by the radiation of the chains of magnetized iron particles. The mutual attraction of unlike polarities is shown by the curved lines.

In Fig. 201, the repulsion of the similarly magnetized chains is clearly shown.

Lines of magnetic force are assumed to pass *out from* the

north pole and into the south pole. This is called the *direction of the lines of force.*

The *density of a magnetic field* is directly proportional to the number of lines of force per unit of area of cross section.

A *single line of force*, or a *unit line of force*, is such an intensity of field as exists in each square centimetre of cross section of a unit magnetic field.

A magnetic field is *uniform*, or possesses *uniform intensity*, when it possesses the same number of lines of force per square centimetre of area of cross section.

Field, Magnetic —— of an Electric Current.—The magnetic field surrounding a circuit through which an electric current is flowing.

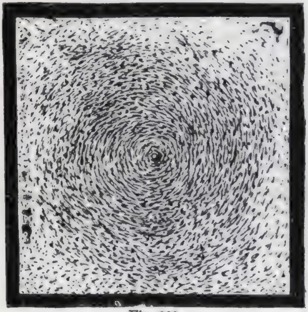


Fig. 202.

An electric current produces a magnetic field. This was discovered by Oersted, in 1819, and may be shown by sprinkling iron filings on a sheet of paper, placed on the wire or conductor conveying the current, at right angles to the direction in which the current is passing. Here the lines of force appear as concentric circles, around the conductor, as shown in Fig. 202. Their direction, as regards the length of the conductor, is shown in Fig. 203. The electric current sets up these *magnetic whirls* around the conductor on its passage through it.

The direction of the lines of magnetic force produced by an electric current, and hence its *magnetic polarity*, depends on

the direction in which the electric current flows. This direction may be remembered as follows: If the current flows towards the observer, the direction of the lines of magnetic force is opposite to that of the hands of a watch, as shown in Fig. 204.

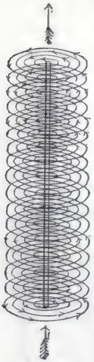


Fig. 203.

It is from the direction of the lines of force that the polarity of a helix carrying a current is deduced. (See *Magnetic Solenoid. Electro-Magnet.*)

A magnetic field possesses the following properties, viz.:

(1) All magnetizable bodies are magnetized when brought into a magnetic field. (See *Induction, Magnetic.*)

(2) Conductors moved through a magnetic field so as to cut its lines of force, have differences of potential generated in them at different points, and if these points be connected by a conductor, an electric current is produced. (See *Induction, Electro-Magnetic.*)

Figure of Merit of Galvanometer.—The reciprocal of the current required to produce a deflection of the galvanometer needle through one degree of the scale.

The smaller the current required to produce a deflection of one degree, the greater the figure of merit, or the greater the sensitiveness of the galvanometer.

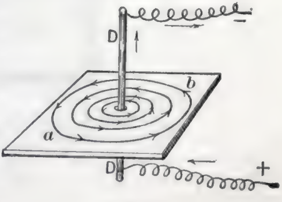


Fig. 204.

Figures, Electric ——— Lichtenberg's Dust Figures.—Figures produced by writing on a sheet of shellac

with a knob of a Leyden jar, and then sprinkling over it a mixture of powdered sulphur and red lead, which have been previously mixed together, and are so rendered, respectively, negative and positive.

The red lead collects on the negative parts of the shellac surface, and the sulphur on the positive parts, in curious figures, known as *Lichtenberg's Dust Figures*, one of which is shown in Fig. 205.

These figures show very clearly that an electric charge tends to creep irregularly over the surface of an insulating substance

Figures, Electric ——— or Breath Figures.—Faint figures of condensed vapor produced by electrifying a coin, placing it momentarily on the surface of a sheet of clean, dry glass, and then breathing gently on the spot where the coin was placed.

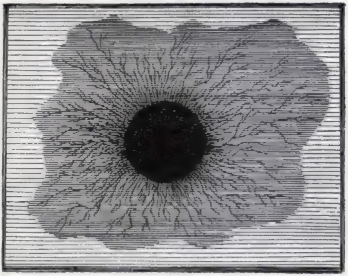


Fig. 205.

The moisture collects on the electrified portions and forms a fairly distinct image of the coin.

Figures, Magnetic ——— —A name sometimes applied to the groupings of iron filings on a sheet of paper held in a magnetic field. (See *Field, Magnetic.*)

Filament.—A slender thread or fibre.

The term is applied generally to threads or fibres varying considerably in diameter.

Filament of Incandescent Electric Lamp.—A term now generally applied to the incandescing conductor of an incandescent electric lamp, whether the same be of very small cross section, or of comparatively large cross section.

The term filament is properly applied to a conductor containing fibres or filaments extending in the general direction of the length of the incandescing conductor. Such a conductor is made of carbonizable fibrous material, cut or shaped prior to carbonization, so as to have the fibres extending with their greatest length in the direction of length of the filament.

Filament, Magnetic—— —— —A chain or thread of magnetized particles.

This is sometimes called a *uniform magnetic filament.*

A bar-magnet possesses but two free poles, which when broken at its *neutral point* or *equator* will develop free poles at the broken ends. This is explained by considering the magnet to be composed of a number of separate particles, separately magnetized. A single chain or filament of such particles is called a *magnetic filament.* (See *Neutral Point of a Magnet. Magnetism, Hughes' Theory of.*)

Fire Alarm, Electric ———— —A system for telegraphically sending an alarm of fire from stations in different portions of a district to the engine houses. (See *Alarm, Electric, Fire.*)

Such alarms are *automatic* when the alarm is sounded by the completion of the circuits by means of a *thermostat.* (See *Thermostat.*)

Fire Extinguisher, Electric —— —— — A thermostat, or a mercury contact, which automatically completes the circuit and turns on a water supply for extinguishing a fire, on a certain predetermined increase of temperature.

Fishes, Electric —— — (See *Animal Electricity. Eel, Electric.*)

Flashing of Carbons, Process for the —— ———A process for improving the electrical uniformity of the carbon conductors employed in incandescent lighting, by the deposition of carbon in their pores, and over their surfaces at those places where the electric resistance is comparatively great.

The carbon conductor is placed in a vessel usually filled with the vapor of a hydro-carbon liquid called rhigolene, or any other readily decomposable hydro-carbon liquid, and gradually raised to electrical incandescence by the passage through it of an electric current. A decomposition of the hydro-carbon vapor occurs, the carbon resulting therefrom being deposited in and on the conductor. If the current is gradually increased, those parts of the conductor which are first rendered incandescent, that is in those parts where the resistance is the highest, and practically those parts only, receive the deposits of carbon. As the current gradually increases, other portions become successively incandescent and receive a deposit of carbon, until at last the filament glows with a uniform brilliancy, indicative of its electric homogeneity.

A carbon whose resistance varies considerably at different parts could not be successfully employed in an incandescent lamp, since if heated by a current sufficiently great to render the points of comparatively small resistance satisfactorily incandescent, the temperature of the points of high resistance would be such as to lower the life of the lamp, while if only those portions were safely heated, the lamp would not be economical. The flashing process is therefore of very great value in the manufacture of an incandescent lamp.

Flashing of Dynamo Electric Machine.—A name given to long, flashing sparks at the commutator, usually due to the short circuiting of the external circuit at the commutator.

Floating Battery, De la Rive's —— — A floating voltaic cell, the terminals of which are connected with a coil

of insulated wire, employed to show the attractions and repulsions between magnets and movable electric circuits.

The cell, shown in Fig. 206, consists of a voltaic couple of zinc and copper, the terminals of which are connected to the circular coil of insulated wire, as shown, and the whole floated by means of a cork, in a vessel containing dilute sulphuric acid.

When the current flows through the coil in the direction shown by the arrows, the approach of the N-seeking pole of a magnet will cause the cell to be attracted or to move towards the magnet pole, since the *south face* or end of the coil is nearer the north pole of the magnet. If the other end were nearer, repulsion would occur, the cell turning around until the south face is nearer the magnet, when attraction occurs.

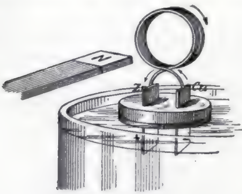


Fig. 206.

Flow.—In hydraulics, the quantity of water or other fluid which escapes from an orifice in a containing vessel in a given time.

Flow —— Direction of Current—— —The direction the current is assumed to take, *i. e.*, from the positive pole of the source through the circuit to the negative pole of the source.

The electricity is assumed to come out of the source at its positive pole, and to return or flow back into the source at its negative pole. (See *Current, Direction of.*)

Flow of Lines of Electrostatic Force.—A mathematical conception in which the phenomena of electricity are compared with the similar phenomena of heat.

In heat no flow of heat occurs over *isothermal surfaces,* or surfaces at the same temperature. Over different isothermal

surfaces the flow will vary with the power of heat conduction. In electricity no flow occurs over *equipotential surfaces. Specific Inductive Capacity* corresponds to heat conductivity, and the lines of force to the lines of heat conduction. (See *Capacity, Specific Inductive.*)

Fluorescence.—A property, possessed by certain solid or liquid substances of becoming self luminous while exposed to the light.

Canary glass, or glass colored yellow by oxide of uranium, and a solution of sulphate of quinine, possess fluorescent properties. The path of a pencil of light brought to a focus in either of these substances is rendered visible, by the particles lying in this path becoming self luminous.

The path of a beam of light, entering the dusty air of a darkened chamber, is visible from the light being diffused or scattered in all directions by the floating dust particles. So in a fluorescent substance the path of the light is also rendered visible by the particles which lie in its path, throwing out light in all directions. There is, however, this difference, that in the case of the dust particles the light which comes directly from the beam is reflected, while in the case of the fluorescent body the light is from the particles themselves, which are set into vibrations by the light that is passing through, and has been absorbed by their mass.

Fluorescence is, therefore, a variety of phosphorescence. (See *Phosphorescence.*)

Flush Boxes.—A box or space, flush with the surface of a road bed, provided in a system of underground wires or conduits, to facilitate the introduction of the conductors into the conduit, or for the examination of the conductors.

Flyer, Electric —— Electric Fly, or Electric Reaction Wheel.—A wheel arranged so as to be set into rotation by the escape of convection streams from its points when placed on a charged conductor.

A wheel formed of light radial arms P, P, shaped as shown in Fig. 207, and capable of rotation on the vertical axis A, is set into rapid rotation when connected with the prime conductor of a machine, through the *convection streams* of air particles which are shot off from the points or extremities of the radial arm. The wheel is driven by the reaction of these streams in a direction opposite to that of their escape. (See *Discharge, Convective.*)

Focus.—The point in front or back of a lens, or mirror, where the rays of light meet. (See *Achromatic Lens.*)

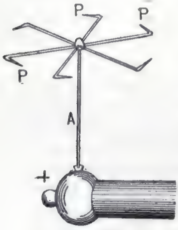


Fig. 207.

Fog, Electric ——— —Dense fogs which occur on rare occasions when there is an unusual quantity of free electricity in the atmosphere.

During these electric fogs the free electricity of the atmosphere changes its polarity at frequent intervals.

Following Horns of Dynamo-Electric Machine. — (See *Horns, Following, of Dynamo-Electric Machine.*)

Foot Candle.—(See *Candle, Foot.*)

Foot-Pound.—A unit of work. (See *Work.*)

The amount of work required to raise one pound vertically through a distance of one foot.

The same amonnt of work is done by raising one pound through a vertical distance of three feet, or three pounds through a vertical distance of one foot, viz., three foot-pounds.

Apart from air friction, the amount of work done in raising one pound through one foot, viz., one foot-pound, is the same whether this work be done in one second, or in one day. The *power*, however, or the *rate of doing work* is very different in the two cases. (See *Power.*)

For another unit of work, see the *Erg*.

Force.—Any cause which changes the condition of rest or motion of a body.

Force, Centrifugal ———(See *Centrifugal Force.*)

Force, Coercive or Coercitive —— or Magnetic Retentivity.—The power of resisting magnetization or de-magnitization. (See *Coercive Force.*)

Force, Composition of ———(See *Components.*)

Force, Electrostatic ———The force producing the attractions or repulsions of charged bodies.

Force, Lines of Electrostatic ———(See *Field, Electro-Static.*)

Force, Lines of Magnetic ———(See *Field, Magnetic.*)

Force, Magnetic ———The force which causes the attractions or repulsions of magnet poles. (See *Magnetic Force.*)

Force, Resolution of ———(See *Resultants.*)

Force, Tubes of —— or Tubes of Induction.—Tubes bounded by lines of electrostatic or magnetic force.

Lines of force never intersect one another. Hence a tube of force may be regarded as containing the same number of lines of force at any and every cross section.

Tubes of electrostatic force always terminate against equal quantities of positive and negative electricity respectively. They terminate when they meet a conducting surface.

The term tubes of force is somewhat misleading, since such so-called tubes are in general *cones* rather than tubes.

Force, Unit of —— or Dyne.—A force, which acting for one second, on a mass of one gramme, will give it a velocity of one centimetre per second. (See *Dyne.*)

Forces, Parallelogram of ———A parallelogram constructed about the two lines that represent the direction and intensity with which two forces are simultaneously acting

on a body, in order to determine the direction and intensity of the resultant force with which it moves.

If the two forces A C and A B, Fig. 208, simultaneously act in the direction of the arrows on a body at A, the direction and intensity of the *resultant*, A D, is determined by drawing D C and B D, parallel respectively to A B, and A C. The diagonal A D, of the parallelogram A C D B, thus produced, gives this resultant. (See *Components.*)

Forming Plates of Secondary or Storage Cells.—Obtaining a thick coating of lead monoxide on the plates of a storage cell, by repeatedly sending the charging current through the cell alternately in opposite directions. (See *Storage of Electricity.*)

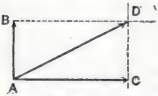


Fig. 208.

Formulæ.—Mathematical expressions for some general rule or principle.

Formulæ are of great assistance in science in expressing the relations which exist between certain forces or values, and the effects that result from their operation, since they enable us to express these relations in clear and concise forms.

Thus, in the formulation of Ohm's law,

$$C = \frac{E}{R},$$

we see that the current C, in any circuit is equal to the electro-motive force E, divided by the resistance R. Again, we see that the current is directly proportional to the electromotive force, and inversely proportional to the resistance.

Formulæ are usually written in the form of an *equation*, and therefore contain the sign of *equality* or =.

Formulæ, Photometric —— —(See *Photometric Formulæ.*)

Foucault Currents, Eddy Currents, Parasitical Currents, Local Action.—(See *Currents, Eddy.*)

Franklinic Electricity.—A term, sometimes employed in electro therapeutics, for the electricity produced by a frictional or an electrostatic induction machine.

Free Charge, Free Electricity.—(See *Charge, Bound and Free.*)

Frictional Electricity.—Electricity produced by friction.

This term as formerly employed to indicate static charges as distinguished from currents, is gradually falling into disuse, and the frictional electric machines, are being generally replaced by continuous induction machines, like those of Holtz, Töpler-Holtz, or Wimshurst.

Frog, Galvanoscopic ——— —The hind legs of a recently killed frog, employed as an *electroscope* or *galvanoscope* by sending an electric current from the nerves to the muscles. (See *Electroscope.*)

Fig. 209.

In 1786, Luigi Galvani, made the observation that when the legs of a recently killed frog were touched by a metallic conductor connecting the nerves with the muscles, the legs were convulsed as though alive. He repeated this experiment, and found the movements were more pronounced when two dissimilar metals, such as iron and copper, were employed in the manner shown in Fig. 209.

This classic experiment created intense excitement in the scientific world, and Galvani at first believed that he had discovered the true vital fluid of the animal, but afterwards

recognized it as electricity, which he believed to be obtained from the body of the animal. Volta, claimed that the movements were due to electricity caused by the contact of dissimilar metals, and thus produced his famous *voltaic pile.* (See *Pile, Voltaic.*)

Fulgurite.—A tube of vitrified sand, believed to be formed by a bolt of lightning.

The fulgurite consists of an irregular shaped tube of glass formed of sand which has been melted by the electric discharge.

Fulminate.—The name of a class of highly explosive compounds.

Fulminating gold, silver, and mercury, are highly explosive substances. Fulminates are employed on percussion caps.

Functions, Trigonometric ——— —(See *Trigonometric Functions.*)

Fundamental Units.—(See *Units, Fundamental.*)

Furnace, Electric ——— —A furnace in which heat, generated electrically, is employed for the purpose of effecting difficult fusions, for the extraction of metals from their ores, or for other metallurgical operations.

In electric furnaces the heat is derived either from electric incandescence, or from the voltaic arc. The latter form is frequently adopted.

The substance to be treated is exposed directly to the voltaic arc. In some forms of furnace the crushed ore is permitted to fall through the arc, and the melted matter received in a suitable vessel, in which the separation of the substances so formed, is afterwards completed. In other forms of furnace, the ore is placed between two electrodes of carbon or other refractory substances, between which a powerful current is passed. In the Cowles furnace, when aluminium is reduced, molten copper forms an alloy with the aluminium as soon as it is separated.

Very numerous applications of electricity to furnace operations have been made, for details of which, standard works should be consulted.

Fuse, Electric ——— —A device for electrically igniting a charge of powder.

Electric fuses are employed both in blasting operations and for firing cannon.

Electric fuses are operated either by means of the direct spark, or by the incandescence of a thin wire, placed in the circuit. They are therefore either *high tension*, or *low tension fuses.*

The advantages of an electric fuse consist in the fact that its use permits the simultaneous firing of a number of charges in a mining operation, thus obtaining a greater effect from the explosion. A fulminate of mercury is frequently employed in connection with some forms of electric fuses.

A form of fuse in which the ignition is effected by the electric spark is shown in Fig. 210, and is known as *Stratham's fuse.* The spark passes through a break A B, in the insulated leads D. Since gunpowder is not readily ignited by an electric spark, a peculiar priming material is employed at A B, in the place of ordinary powder.

Fig. 210.

Fuse, Safety ——— **Safety Strip, or Safety Plug.**—A strip, plate, or bar of lead or some readily fusible alloy, that automatically breaks the circuit in which it is placed on the passage of a current of sufficient power to fuse such strip, plate, or bar, when such current would endanger the safety of other parts of the circuit.

Safety fuses are made of alloys of lead, and are placed in boxes, lined with non-combustible material, in order to prevent fires from the molten metal. Fig. 211, shows a fusible strip F, connected with leads L, L. Safety fuses are placed

on all branch circuits, and are made of sizes proportionate to the number of lamps they guard.

Since incandescent lamps are generally connected with the circuit in *multiple-arc*, or in *multiple-series*, one or more of the circuits can be opened by the fusion of the plug without interfering with the continuity of the rest of the circuit. In *series circuits*, however, such as arc light circuits, when a lamp is cut out, a short circuit or path around it must be provided to avoid the extinguishing of the rest of the lights.

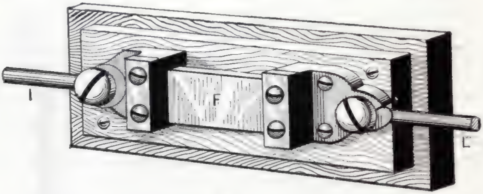


Fig. 211.

Galvanic Battery—Two or more voltaic cells so arranged as to form a single source. (See *Battery, Voltaic.*)

Galvanic Cell.—(See *Cell, Voltaic.*)

Galvanic Circle.—(See *Circle, Galvanic.*)

Galvanic Circuit.—A term sometimes employed instead of the term voltaic circuit. The term galvanic in place of voltaic is unwarranted by the facts of electric science. (See *Circuit, Voltaic.*)

Galvani thought he had discovered the vital fluid of animals. Volta first pointed out the true explanation of the phenomena observed in Galvani's frog, and devised the means for producing electricity in this manner. The terms *voltaic battery, cell, circuit, etc.*, are therefore preferable.

Galvanic Polarization.—A term sometimes applied to the polarization of a voltaic cell. (See *Polarization of Voltaic Cell.*)

Galvanism.—A term sometimes employed to express the effects produced by voltaic electricity.

Galvanization.—In electro therapeutics the effects produced on nervous or muscular tissue by the passage of a voltaic current.

In electro-metallurgy, the process of covering any conducting surface with a metallic coating by electrolytic deposition, such, for example, as the thin copper coating deposited on the carbon pencils or electrodes used in systems of arc lighting.

This term is borrowed from the French, in which it has the above signification. It is preferably replaced by the term *electro-plating.* (See *Electro-Plating.*)

It is never correctly applied to the process for covering iron with zinc or other metal by dipping the same in a bath of molten metal.

Galvanized Iron.—Iron covered with a layer of zinc by dipping in a bath of molten zinc.

The process of galvanizing iron is designed to prevent the corrosion or rusting of the iron on exposure to the air. (See *Metals, Electrical Protection of.*)

Galvano-Cautery.—(See *Cautery, Electric.*)

Galvano-Faradization.—In electro therapeutics the simultaneous excitation of a nerve or muscle by both a *voltaic* and a *faradic* current.

Galvanometer.—An apparatus for measuring the strength of an electric current by the deflection of a magnetic needle.

The galvanometer depends for its operation on the fact that a conductor, through which an electric current is flowing,

will deflect a magnetic needle placed near it. This deflection is due to the *magnetic field* caused by the current. (See *Field, Magnetic, of Current.*)

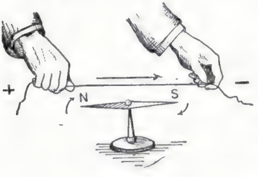


Fig. 212.

This action of the current was first discovered by Oersted. A wire conveying a current in the direction shown by the straight arrow, Fig. 212, or from + to —, will deflect a magnetic needle in the direction shown by the curved arrows.

If the wire be bent in the form of a hollow rectangle F D E G, Fig. 213, and the needle, M, be placed inside the circuit, the upper and lower branches of the current, will deflect the needle in the same direction, and the effect of the current will thus be multiplied. Mercury cups are provided at A, B and C, for a ready change in the direction of the circuit. (See *Astatic Needle.*)

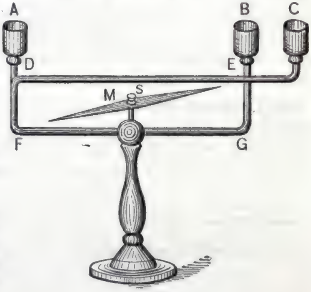


Fig. 213.

This principle of the multiplication of the deflecting power of the current was applied to galvanometers by Schweigger, who used a number of turns of insulated wire for the greater deflection of the needle. He called such a device a *multiplier*. In extremely sensitive galvanometers very many turns of wire are employed, in some cases amounting to many thousands. Such galvanometers are of a *high resist-*

ance. Others, of *low resistance*, often consist of a single turn of wire and are used in the direct measurement of large currents.

A Schweigger's multiplier or coil C C, of many turns of insulated wire, is shown in Fig. 214. The action of such a coil, on the needle M, is comparatively great, even when the current is small.

In the case of any galvanometer, the needle when at rest, and no current is passing, should in general, occupy a position parallel to the length of the coil. On the passage of the current the needle tends to place itself in a position at right angles to the direction of the current, or to the length of the conducting wire in the coil. The strength of the current passing is determined by observing the amount of this deflection as measured in degrees on a graduated circle over which the needle moves.

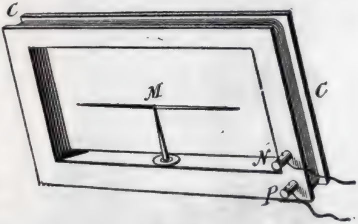


Fig. 214.

The needle is deflected by the current from a position of rest, either in the earth's magnetic field, or in a field obtained from a permanent, or an electro magnet. In the first case, when in use to measure a current, the plane of the galvanometer coils must coincide with the plane of the magnetic meridian. In the other case, the instrument may be used in any position in which the needle is free to move.

Galvanometers assume a variety of forms according either to the purposes for which they are employed, or to the manner in which their deflections are valued.

Galvanometer, Absolute —— —A galvanometer with an *absolute calibration*. (See *Calibration, Absolute.*)

Such a galvanometer is called absolute because if the dimensions of its coil and needle are known, the current can be determined directly from the observed deflection of the needle.

Galvanometer, Aperiodic ——— —(See *Galvanometer, Dead Beat.*)

Galvanometer, Astatic ——————— —A galvanometer, the needle of which is *astatic.* (See *Astatic Needle.*)

Nobili's astatic galvanometer is shown in Fig. 215. The astatic needle, suspended by a fibre *b*, has its lower needle placed inside a coil *a*, consisting of many turns of insulated wire, its upper needle moving over the graduated dial. The current to be measured is led into and from the coil at the binding posts *x* and *y*.

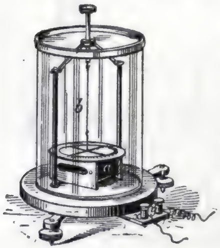


Fig. 215.

In this instrument, if small deflections only are employed, the deflections are sensibly proportional to the strength of the deflecting currents.

Galvanometer, Ballistic ——————— —A galvanometer designed to measure the strength of currents that last but for a moment, such for example, as the current caused by the discharge of a condenser.

The quantity of electricity passing in any circuit is equal to the product of the current and the time. Since the current caused by the discharge of a condenser lasts but for a small time, during which it passes rapidly from zero to a maximum and back again to zero, the magnetic needle in a ballistic galvanometer takes the form of a ballistic pendulum, *i. e.*, it is given such a mass, and acquires such a slow motion, that its change of position does not practically begin until the impulses have ceased to act.

In the ballistic galvanometer of Siemens and Halske, the coils R, R, Fig. 216, have a bell-shaped magnet M, suspended

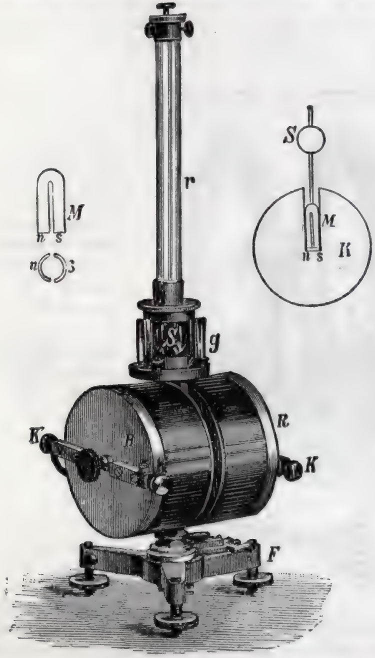


Fig. 216.

inside them by means of an aluminium wire. The magnet is

provided with a mirror S, for measuring the deflections. The bell-shaped magnet is shown in elevation at M, and in plan at *n*, *s*.

In using the ballistic galvanometer it is necessary to see that the needle is absolutely at rest before the discharge is sent through the coils.

Galvanometer, Dead Beat —— —A galvanometer, the needle of which comes quickly to rest, instead of swinging repeatedly to and fro. (See *Damping*.)

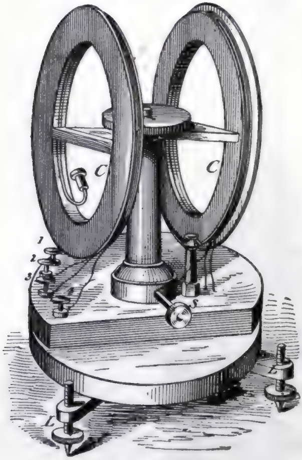


Fig. 217.

Galvanometer, Differential —— A galvanometer containing two coils so wound as to tend to deflect the needle in opposite directions.

The needle of a differential galvanometer shows no deflection when two equal currents are sent through the coils in opposite directions, since, under these conditions each coil neutralizes the other's effects. Such instruments may be used in comparing resistances. The *Wheatstone Bridge*, however, in most cases, affords a preferable method for such purposes. (See *Balance, Wheatstone's*.)

A form of differential galvanometer is shown in Fig. 217.

Sometimes the current is sent through the two coils so that each coil deflects the needle in the same direction. In this case, the instrument is no longer differential in action. If the magnetic needle, in such cases, is suspended at the exact centre of the line which joins the centres of the coils, the advantage is gained of obtaining a field of more nearly uniform intensity around the needle.

Galvanometer, Figure of Merit of ————————(See *Figure of Merit of Galvanometer.*)

Galvanometer, Marine ———— —A galvanometer devised by Sir Wm. Thomson for use on steamships where the motion of magnetized masses of iron would seriously disturb the needles of ordinary instruments.

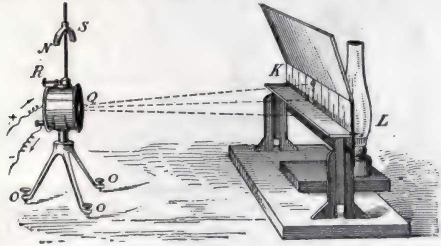


Fig. 218.

The needle of the marine galvanometer is shielded or cut off from the extraneous fields so produced, by the use of a *magnetic screen* or *shield*, consisting of an iron box with thick sides, *inside of which* the instrument is placed.

The needle is suspended by means of a silk fibre attached *both above and below*, and passing through the *centre of gravity* of the needle. In this manner the oscillations of the ship do not affect the needle.

Galvanometer, Mirror —A galvanometer in which, instead of reading the deflections of the needle directly by its movement over a graduated circle, they are read by the movements of a spot of light reflected from a mirror attached to the needle.

This spot of light moves over a graduated scale, or its movements are observed by means of a telescope.

A form of mirror galvanometer designed by Sir Wm. Thomson, is shown in Fig. 218. The needle is attached directly to the back of a light, silvered glass mirror, and consists of several small magnets made of pieces of a watch spring. The needle and mirror are suspended by a single silk fibre and are placed inside the coil. A *compensating magnet* N S, movable on a vertical axis, is used to vary the sensitiveness of the instrument. The lamp L, placed back of a slot in a wide screen, throws a pencil of light on the mirror Q, from which it is reflected to the scale K.

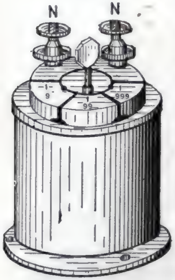


Fig. 219.

Galvanometer Shunt.—A shunt placed around a sensitive galvanometer for the purpose of protecting it from the effects of a strong current, or for altering its sensibility. (See *Shunt.*)

The current which will flow through the shunt wire depends on the relative resistance of the galvanometer and of the shunt. In order that only $\frac{1}{10}$, $\frac{1}{100}$ or $\frac{1}{1000}$ of the total current shall pass through the galvanometer, it is necessary that the resistances of the shunt shall be the $\frac{1}{9}$, $\frac{1}{99}$ or $\frac{1}{999}$ of the galvanometer resistance.

Fig. 219, shows a shunt, in which the resistances, as compared with that of the galvanometer are those above referred to. The galvanometer terminals are connected at N N. Plug

keys are used to connect one or another of the shunts into the circuit. (See *Multiplying Power of Shunt.*)

Galvanometer, Sine ——— —A galvanometer in which a vertical coil is movable around a vertical axis, so that it can be made to follow the magnetic needle in its deflections.

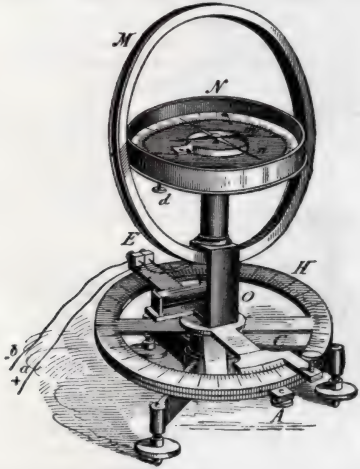


Fig. 220.

In the sine galvanometer the coil is moved so as to follow the needle, until it is parallel with the coil. Under these circumstances the strength of the deflecting currents in any two different cases is proportional to the *sine* of the angle of deflection.

A form of sine galvanometer is shown in Fig. 220. The vertical wire coil is seen at M. A needle, of *any length less than the diameter of the coil M*, moves over the graduated circle N. The coil M, is movable over the graduated horizontal circle H, by which the amount of the movement necessary to bring the needle to zero is measured. The current strength is proportional to the *sine* of the angle measured on this circle, through which it is necessary to move the coil M from its position when the needle is at rest in the plane of the earth's magnetic meridian, until the needle is not further deflected by the current, although parallel to the coil M.

Galvanometer, Tangent —— —An instrument in which the deflecting coil consists of a coil of wire within which is placed a needle very short in proportion to the diameter of the coil, and supported at the centre of the coil.

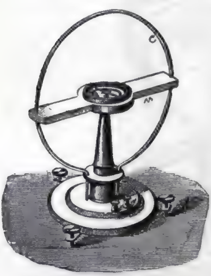


Fig. 221.

A galvanometer acts as a tangent galvanometer only when the needle is very small as compared with the diameter of the coil. The length of the needle should be less than one-twelfth the diameter of the coil.

A form of tangent galvanometer is shown in Fig. 221. The needle is supported at the exact centre of the coil C.

Under these circumstances the strengths of two different deflecting currents are proportional to the *tangents* of the angles of deflection. Tangent galvanometers are sometimes made with coils of wire containing many separate turns.

Galvanometer, Tangent, —— Obach's.—A form of galvanometer in which the deflecting coil, instead of being in a fixed vertical position, is movable about a horizontal

axis, so as to decrease the delicacy of the instrument, and thus increase its range of work.

Galvanometer, Torsion —— —A galvanometer in which the strength of the deflecting current is measured by the torsion exerted on the suspension system.

A bell-shaped magnet, shown at the right of Fig. 222, is suspended by *a thread and a spiral spring* between two coils of high resistance, placed parallel to each other in the positions shown. On the deflection of the magnet, by the current to be measured, the strength of the current is determined by the amount of the torsion required to bring the magnet back to its zero point. The angle of torsion is measured on the horizontal scale at the top of the instrument.

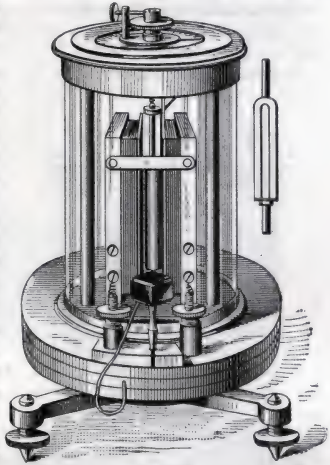


Fig. 222.

In the torsion galvanometer, unlike the electro-dynamometer, the action between the coils and the movable magnet is as the *current strength causing the deflection.* In the *electro dynamometer,* such an increase in the deflecting coil produces a corresponding increase in the deflected coil; the mutual action of the two is as the *square of the current strength causing the deflection.*

Galvanometer, Vertical —— —A galvanometer, the needle of which is capable of motion in a vertical plane only.

In the vertical galvanometer the north pole is weighted so that the needle assumes a vertical position when no current is passing. In the form shown, in Fig. 223, two needles are sometimes employed, one of which is placed inside the coils C, C.

The vertical galvanometer is not as sensitive as the ordinary forms. It is employed, however, in various forms for an electric current indicator or even for a rough current measurer.

Galvanometer, Volt-Meter —— —An instrument devised by Sir Wm. Thomson, for the measurement of differences of electric potential.

This instrument is so arranged that by a simple correction for the varying strength of the earth's field in any place, the results are read at once in *volts*.

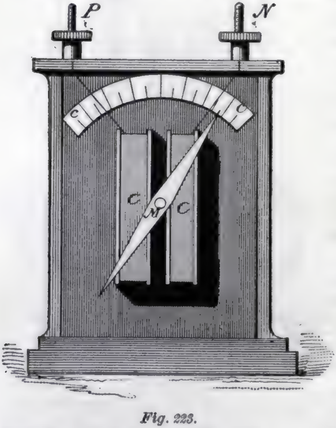


Fig. 223.

A coil of insulated wire, shown at A, Fig. 224, has a resistance of over 5,000 ohms. A magnetic needle, formed of short parallel needles placed above one another and called a *magnetometer needle*, is attached to a long but light aluminium index, moving over a graduated scale. A movable, semi-circular magnet B, called the *restoring magnet*, is placed over the needle, and is used for varying the effect of the earth's field

at any point. The sensitiveness of the instrument may be varied either by the restoring magnet, or by sliding the *magnetometer box* nearer to, or further away from the coil.

The volt-meter galvanometer depends for its operation on the fact that when a galvanometer of sufficiently high resistance is introduced between any two points in a circuit, the current that passes through it, and hence the deflection of its needle, is directly proportional to the difference of potential between such two points.

Galvanometers for the commercial measurement of currents assume a variety of forms. They are generally so constructed as to read off the *ampères, volts, ohms, watts,* etc., directly. They are called *ampèremeters* or *ammeters, voltmeters, ohmmeters, wattmeters,* etc. For their fuller description reference should be had to standard electrical works.

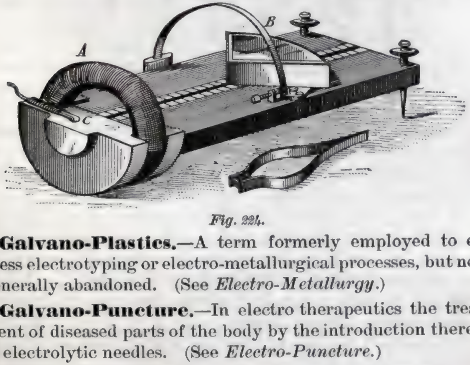


Fig. 224.

Galvano-Plastics.—A term formerly employed to express electrotyping or electro-metallurgical processes, but now generally abandoned. (See *Electro-Metallurgy.*)

Galvano-Puncture.—In electro therapeutics the treatment of diseased parts of the body by the introduction therein of electrolytic needles. (See *Electro-Puncture.*)

Galvanoscopic Frog.—(See *Frog, Galvanoscopic.*)

Gas-Battery.—A battery in which the elements consumed are gases as distinguished from solids.

The electrodes of a gas battery generally consist of plates of platinum, or other solid substance which possesses the power of occluding oxygen and hydrogen, the lower parts of which plates dip into dilute sulphuric acid, and the upper parts are respectively surrounded by oxygen and hydrogen gas derived from the electrolytic decomposition of the dilute acid.

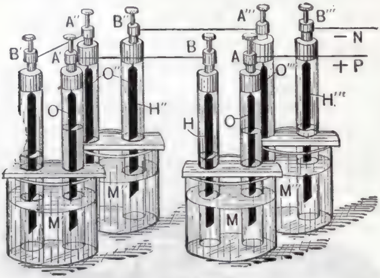


Fig. 225.

A gas battery consisting of plates of platinum dipping below into acid liquid, and surrounded in the space above the liquid by hydrogen and oxygen H, H′ and O, O′, etc., respectively, is shown in Fig. 225.

In charging this battery an electric current is sent through it until a certain quantity of the gases has been produced. If, then the charging current be discontinued, a current in the opposite direction is produced by the battery. The gas battery is in reality a variety of *storage battery.* (See *Storage of Electricity. Storage Cells.*)

Gas batteries can also be made by feeding continually a gas capable of acting on the positive elements.

Gas Burner, Automatic ——— —(See *Burner, Automatic.*)

Gas Jet Photometer.—A photometer for determining the intensity of gas light by measuring the length of the gas jet producing the light when burning under certain circumstances.

Gas Lighting, Electric —— ——— —Various devices employed for the simultaneous electric ignition of a number of gas jets from a distance.

Such devices are operated by means of minute electric sparks which are caused to pass through the escaping gas jets.

The spark for this purpose is obtained either by means of the *extra current* from a *spark coil*, by means of an *induction coil* or by static discharges. (See *Extra Current. Spark Coil. Induction Coil.*)

Gases, Occlusion of ——— —(See *Occlusion of Gases,*)

Gastroscope.—An electric apparatus for the illumination and inspection of the human stomach.

The light is obtained by means of a platinum spiral in a glass tube surrounded by a layer of water to prevent undue heating. The platinum spiral is placed at the extremities of a tube, provided with prisms, and passed into the stomach of the patient. A separate tube for the supply of air for the extension of the stomach is also provided.

Gauge, Electrometer ——— —A device employed in connection with some of Sir Wm. Thomson's electrometers to ascertain whether the needle connected with the layer of acid that acts as the inner coating of the Leyden jar used in connection therewith, is at its normal potential.

The gauge consists, as shown in Fig. 226, of an attracted disc electrometer. The attracted disc is shown above in the cover plate at S, and the attracting disc at B, insulated by rod A, but electrically connected by the wire C to the sulphuric acid in the Leyden jar.

Gauge, Wire ——— —(See *Wire Gauge.*)

Gauss.—The unit of intensity of magnetic field.

The term gauss for unit of intensity of magnetic field was proposed by S. P. Thompson as being that of a field whose intensity is equal to 10^8 C. G. S. units. J. A. Fleming proposes for the value of the gauss such a strength of field as would develop an electro-motive force of one volt, in a wire one million centimetres in length, moving through such a field with unit velocity.

Fleming's value for the gauss was assumed on account of the small value of the gauss proposed by S. P. Thompson. It is 100 times greater in value than Thompson's gauss.

Sir Wm. Thomson proposes for the value of the gauss such an intensity of magetic field as is produced by a current of one (ampère) weber at the distance of one centimetre.

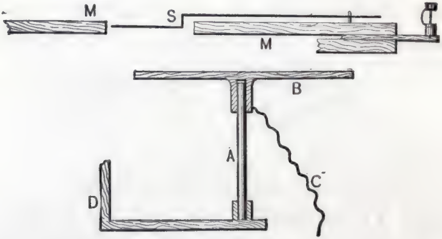


Fig. 226.

Geissler Tubes.—Vacuum tubes of glass, provided with platinum electrodes which are passed through and fused into the glass, and designed to show the various luminous effects of electric discharges through comparatively low vacua.

Geissler tubes are made of a great variety of shapes, and often include tubes, spirals, spheres, etc,, within other tubes. These inclosed tubes are made either of ordinary glass, or of uranium glass in order to obtain the effects of fluorescence, or some of the inclosed tubes are filled with fluorescent liquids.

The vacuum in Geissler tubes is by no means what might be called a high vacuum. Indeed, if the exhaustion of the tube be pushed too far, much of the brilliancy of the luminous effects are lost.

Two of the many forms of Geissler tubes is shown in Fig. 227.

Generator, Dynamo-Electric ———— —An apparatus in which electricity is produced by the mechanical movement of conductors in a magnetic field so as to cut the lines of force.

A dynamo-electric machine. (See *Dynamo-Electric Machine.*)

Generator, Pyro-Magnetic ———— —An apparatus in which electricity is produced by the combined action of heat and magnetism. (See *Pyro-Magnetic Generator.*)

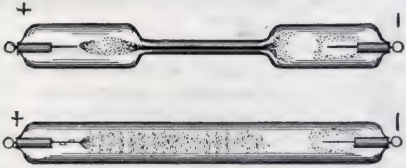


Fig. 227.

Generator, Secondary —— (See *Secondary Generator.*)

Geographical Equator. (See *Equator, Geographical.*)

Geographical Meridian. (See *Meridian, Geographical.*)

Gilding, Electric ——— —The electrolytic deposition of gold on any object.

The object to be gilded is rendered a conductor on its surface and connected to the negative terminal of a voltaic cell or other source, and immersed in a plating bath containing a so-

lution of a salt of gold, opposite a plate of gold connected with the positive terminal of the source. The objects to be plated thus becomes the kathode, and the plate of gold the anode of the plating bath. On the passage of the current, the gold is dissolved from the plate at the anode and deposited on the object at the kathode. (See *Kathode. Anode.*)

Gimbals.—Concentric rings of brass, suspended on pivots in a compass box, and on which the compass card is supported so as to enable it to remain horizontal notwithstanding the movements of the ship. (See *Azimuth Compass.*)

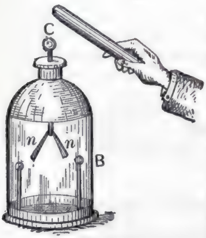


Fig. 228.

Each ring is suspended on two pivots which are directly opposite each other, that is, at the ends of a diameter, but this diameter in one ring is at right angles to that in the other.

Globular Lightning.—A variety of lightning in which the electricity appears in the form of a ball or globe which floats quietly about, and at last explodes with a loud detonation.

Its cause is but little understood. The actual existence of these balls or globes is doubted by some, who regard them as optical effects produced by the persistence of the optical impression of a discharge.

Glow Discharge. (See *Discharge, Convective.*)

Gold Bath. (See *Baths, Gold,* etc.)

Gold-Leaf Electroscope.—An electroscope in which two leaves of gold are used to detect the presence of an electric charge, or to determine its character whether positive or negative.

When a charge is imparted to the knob C, Fig. 228, the

gold leaves *n*, *n*, diverge. This will occur whether the charge be positive or negative.

To determine the polarity of an unknown charge, the leaves are first caused to diverge by means of a known positive or negative charge. The unknown charge is then given to the leaves. If they diverge still further, then the charge is of the *same name* as that originally possessed by the leaves. If, however, they first *move together* and are then repelled, the charge is of the *opposite name.*

Governor, Centrifugal —— (See *Centrifugal Governor.*)

Governor, Electric Steam ——— —A device used in connection with a valve to so electrically regulate the supply of steam to an engine, that the engine shall be driven at such a speed as will maintain either a constant current or a constant potential.

In the electric governor the steam valve is operated by an electro magnet, whose coils, in the case of a constant current machine, are of thick wire and are in the main circuit, and in that of a constant potential machine are of thin wire and are in a shunt around the mains.

Governors, Electric ——— —Devices for electrically controlling the speed of a steam engine, the direction of current in a plating bath, the speed of an electric motor, the resistance of an electric circuit, the flow of water or gas into or from a vessel, or for other similar purposes.

The particular form assumed by the apparatus varies with the character of the work it is intended to accomplish. In some cases ordinary ball centrifugal governors are employed to open or close a circuit; or, a mass of mercury in a rotating vessel is caused at a certain speed to open or close a circuit; or, the resistance of a bundle of carbon discs is caused to vary, either by pressure produced by *centrifugal force;* or by the movement of an armature.

Gramme.—A weight equal to 15.43235 grains. (See *Metric System of Weights and Measures.*)

Gramme Atom.—(See *Atom, Gramme.*)

Gramme Molecule.—(See *Molecule, Gramme.*)

Gramophone.—An apparatus for the recording and reproduction of articulate speech. (See *Phonograph.*)

Graphite.—A soft variety of carbon suitable for writing on paper or similar surfaces.

Graphite is the material that is employed for the so-called black lead of lead pencils. It is sometimes called *plumbago.* Strictly speaking the term graphite is only applicable to the variety of plumbago suitable for use in lead pencils.

Graphite is used for rendering surfaces to be plated electrically conducting, and also for the brushes of dynamos and motors.

Graphophone.—An apparatus for the recording and reproduction of articulate speech. (See *Phonograph.*)

Gravitation.—A name applied to the force which causes masses of matter to tend to move towards each other.

This motion is assumed to be that of attraction, that is, the bodies are assumed to be *drawn together.* It is not impossible, however, that they may be *pushed together.*

Gravitation, like electricity, is well known, so far as its effects are concerned; but, as to the true cause of either, particularly the former, we are in comparative ignorance.

The general facts of gravitation may be succinctly stated by the following law:

Every particle of matter in the universe is attracted by every other particle of matter, and itself attracts every other particle of matter, with a force which is directly proportional to the product of the masses of the two quantities of matter and inversely proportional to the square of the distance between them.

Gravity, Centre of ——.—The centre of weight of a body.

Bodies supported at their centres of gravity are in equilibrium, since their weight is then evenly distributed around the point of support.

Grenet's Voltaic Cell.—(*Cell, Voltaic.*)

Grid.—A lead plate in the form of a gridiron, *i. e.*, provided with perforations, and employed in storage cells for the support of the active material. (See *Secondary Cells.*)

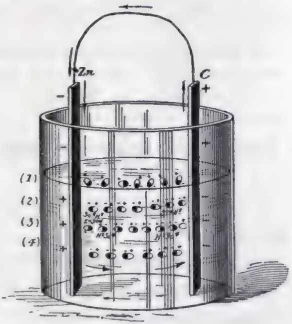


Fig. 229.

Grothüss' Hypothesis.—A hypothesis devised by Grothüss to account for the electrolytic phenomena that occur on closing the circuit of a voltaic cell.

This hypothesis assumes

(1) That before the circuit is closed, the molecules of the electrolyte are arranged in an irregular or *unpolarized* condition, asrepresented in Fig. 229.

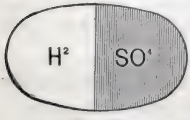


Fig. 230.

These molecules are shaded, as shown in Fig. 230, to indicate their composition and polarity.

(2) When the circuit is closed, and a current begins to pass, a *polarization* of the *electrolyte*, as shown at (2), ensues, whereby all the negative ends of the molecules of hydrogen sulphate, or sulphuric acid, are turned towards the *positive*, or the zinc plate, and

the positive ends, towards the negative, or the copper plate. This, as will be seen, will turn the SO_4 ends toward the zinc, and the H_2 ends towards the copper.

(3) A decomposition of the polarized chain whereby the SO_4 unites with the zinc, forming $Zn\,SO_4$, and the H_2 liberated reunites with the SO_4 of the molecule next to it in the chain, and its liberated H_2 with the one next to it, until the last liberated H_2 is given off at the surface of the copper or negative plate. This leaves the chain of molecules as shown at (3).

(4) A semi-rotation of the molecules of the chain as at (3), until they assume the position shown at (4). This rotation is required since the molecules in (3) are turned with their similar poles towards similarly charged battery plates.

Ground or Earth-Grounded Wire.—The earth or ground which forms part of the return path of an electric circuit.

A circuit is grounded when it is completed in part by the *ground* or *earth.*

Grounded Circuit.—(See *Circuit, Grounded.*)

Grove's Voltaic Cell.—(See *Cell, Voltaic.*)

Gutta-Percha.—A resinous gum obtained from a tropical tree, and valuable electrically for its high insulating powers.

Gutta-percha readily softens by heat, but on cooling becomes quite hard and tough. Unlike india rubber, it possesses but little elasticity. Its *specific inductive capacity* is 4.2, that of air being 1, and of vulcanized india rubber 2.94. (See *Capacity, Specific Inductive.*)

Gymnotus Electricus.—The *electric eel.* (See *Eel, Electric.*)

Hail, Assumed Electric Origin of —— —A hypothesis, now generally rejected, framed to explain the origin of the alternate layers of ice and snow in a hail stone,

by the alternate electric attractions and repulsions of the stones between neighboring, oppositely charged, snow and rain clouds.

It is now generally recognized that the electric manifestations attending hail storms, are the *effects* and not the *causes* of the hail. (See *Paragrêles.*)

Hair, Electrolytic Removal of —— —The permanent removal of hair by the electrolytic destruction of the hair follicles.

A negative platinum electrode is inserted in the hair follicle and the positive electrode, covered with moist sponge or cotton, is held in the hand of the patient. A current of two to four *milliampères* from a battery of from eight to ten Leclanché elements is then passed for from ten to thirty seconds. A few bubbles of gas appear, and the hairs are then removed from the follicle by a pair of forceps. (See *Milliampères.*)

When the work is properly done there is no destruction of the skin and therefore no marks or scars.

In the removal of hair from the face, it is preferable that the current should slowly reach its maximum strength.

Hall Effect.—(See *Effect, Hall.*)

Hanger-Board of Electric Lamp.—A board furnished with a hand switch and hooks for connecting it with a circuit, and provided with means for readily placing an arc lamp in the circuit.

The lamp is connected by the mere act of hanging it in position, though binding posts are generally connected with the board, for the purpose of more thoroughly connecting the lamp terminals with the circuit.

Hanger, Cable —— or Clip.—(See *Cable Clip.*)

Harmonic Receiver.—(See *Receiver, Harmonic.*)

Harmonic Telegraphy.—(See *Telegraphy, Harmonic.*)

Head Light, Locomotive Electric —— —An

electric light placed in the focus of a parabolic reflector in front of a locomotive engine. (See *Light House Illumination.*)

Heat.—A form of energy.

The phenomena of heat are due to a vibratory motion impressed on matter by the action of some form of energy.

Heat in a body is due to the vibrations or oscillations of its molecules. Heat is transmitted through space by means of a wave motion in the universal ether. This wave motion is the same as that causing light.

A hot body loses its heat by producing a wave-motion in the surrounding ether. This process is called *radiation.*

Radiant Energy, or energy transmitted by means of ether waves, is of two kinds, viz.:

(1) *Obscure Heat,* or heat, which does not affect the eye, although it can impress a photographic image on a sufficiently sensitive photographic plate.

(2) *Luminous Heat,* or heat which accompanies light.

Heat is conducted, or transmitted through bodies, with different degrees of readiness.

Some bodies are good conductors of heat, others are poor conductors.

Heat is transmitted through the mass of liquids by means of currents occasioned by differences in density caused by differences of temperature. These currents are called *convection currents.*

Heat is measured as to its *relative degree of intensity* by the *thermometer.* It is measured as to its *amount* or *quantity* by the *calorimeter.* (See *Thermometer. Calorimeter.*)

The heat unit is the *calorie,* or the amount of heat required to raise one gramme of water one degree centigrade.

Another *heat unit,* very generally employed in the United States and England, is the quantity of heat required to raise one pound of water 1° Fahrenheit. (See *Calorie. Heat Unit, English. Joule. Volt-Coulomb.*)

Heat, Absorption and Generation of —— in Voltaic Cells.—The heat effects which attend the action of a voltaic cell.

The chemical solution of the positive plate or element of a voltaic cell, like all cases of chemical combination, is attended by a development of heat.

When, however, the circuit of the cell is closed, the energy liberated during the chemical combination, appears as electricity, which develops heat in all parts of the circuit. (See *Heat, Electric. Cell, Voltaic.*)

Heat, Atomic —— —A constant product obtained by multiplying the specific heat of an elementary substance by its *atomic weight.* (See *Atomic Weight.*)

The product of the specific heat of all elementary substances by their atomic weights is nearly the same. This product is called the *atomic heat,* and is about equal to 6.4.

If, therefore, a number of grammes of any substance, such for example as chlorine, be taken numerically equal to its atomic weight, viz., 35.5, this number, called the *gramme atom of chlorine,* will represent the number of *small calories of heat* required to raise one gramme-atom of such substance through 1° C. (See *Calorie.*)

Heat, Electric —— —The heat developed by the passage of the electric current through any conductor.

Heat is developed by the passage of the current through any conductor, no matter what its resistance may be.

If the conductor is of considerable length, and of good conducting power, the heat developed is not very sensible since it is spread over a considerable area, and is rapidly lost by *radiation.* (See *Heat.*)

H, the heat generated in any conductor of a resistance R, by the passage through it of an electric current C, is equal to

$$H = C^2 R, \text{ in watts.}$$

But one watt = .24 small calorie per second.

Therefore, the heat which is generated,

$$H = C^2 R \times .24 \text{ calories per second.}$$

For the case of a uniform wire of circular cross section the resistance R, in ohms, is directly proportional to the length l, and inversely proportional to the area of cross section πr^2, or

$$R = \frac{l}{\pi r^2}, \text{; that is, } H = C^2\left(\frac{l}{\pi r^2}\right) \cdot$$

The temperature to which a wire of a given resistance is raised, will of course vary with the mass of the wire, its radiating surface, and its specific heat capacity. If the same number of heat calories are generated in a small weight of a conductor, whose radiating surface is small, the resulting temperature will of course be far higher than if generated in a larger mass provided with a much greater radiating surface. In general, however, its temperature increases as the square of the current strength, and as the resistance of the wire per unit of length is greater.

The temperature a wire acquires by the passage of a current through it varies with the third power of the radius. If two wires of the same material have the same lengths, but different radii, the temperature acquired by the passage of an electric current will depend on the heat developed per second less that radiated per second. Since the former varies as $\frac{1}{r^2}$, and the latter as r, that is, as $l \times 2\pi r$, the temperature attained varies as $\frac{1}{r^3}$, and not as $\frac{1}{r^2}$, as frequently stated. (*Larden.*)

The current required to raise the temperature of a bare copper wire a given number of degrees above the temperature of the air is given in the following table

Bare Copper Wires.

Current required to increase the temperature of a copper wire t° centigrade above the surrounding air, the copper wire being bright polished, or blackened.

Diameter in Centimetres and Mils (thousanths of an inch.)		CURRENT IN AMPÈRES.									
		t. = 1° c.		t. = 9° c.		t. = 25° c.		t. = 49° c.		t. = 81° c.	
Cm.	Mills.	Brght	Black	Brght	Black	Brght	Black	Brght	Black	Brght	Black
.1	40	1.0	1.4	3.0	4.1	4.8	6.6	6.5	8.9	7.9	11.0
.2	80	2.8	3.9	8.3	11.5	13.5	18.7	18.3	25.3	22.4	31.0
.3	120	5.2	7.2	15.3	21.2	24.9	34.4	33.5	46.4	41.2	57.0
.4	160	8.0	11.0	23.6	32.7	38.3	53.0	51.7	71.5	63.4	87.8
.5	200	11.1	15.4	33.0	45.7	53.5	74.1	72.2	99.9	88.6	123
.6	240	14.6	20.3	43.4	60.0	70.3	97.4	94.9	131	116	161
.7	280	18.5	25.6	54.6	75.6	88.7	123	119	165	147	203
.8	310	22.6	31.2	66.7	92.4	108	150	146	202	179	248
.9	350	26.9	37.3	79.6	110	129	179	174	241	214	296
1.0	390	31.5	43.6	93.3	129	151	210	204	283	251	347
2.0	790	89.2	123	264	365	428	593	577	799	709	981
3.0	1180	164	227	485	671	787	1090	1061	1468	1303	1805
4.0	1570	252	349	746	1035	1211	1675	1633	2260	2006	2776
5.0	1970	353	488	1043	1444	1692	2343	2283	3160	2802	3880
6.0	2360	463	642	1371	1898	2225	3080	3000	4154	3685	5100
7.0	2760	584	808	1728	2392	2803	3882	3781	5233	4642	6426
8.0	3150	714	988	2110	2922	3422	4741	4620	6396	5671	7850
9.0	3540	851	1178	2519	3486	4088	5659	5511	7630	6769	9370
10.0	3940	997	1380	2950	4081	4788	6626	6425	8935	7926	10973
34.4	....	....	....	....	....	....	....	....	....	....	70000

(*Forbes.*)

Heat, Molecular ——— The number of calories of heat required to raise the temperature of one *gramme-molecule* of any substance 1° C. (See *Heat, Atomic.*)

Heat, Specific ——— —The capacity of a substance for heat as compared with the capacity of an equal quantity of water for heat.

Different amounts or quantities of heat are required to raise the temperature of a given weight of different substances through one degree. The specific heats of substances are generally compared with water or with hydrogen, the capacity of these substances for heat being very great.

The specific heat of all elementary atoms is the same. For example, the heat energy of an atom of hydrogen is equal to that of an atom of oxygen, but since the latter weighs sixteen times as much, a given mass of hydrogen contains sixteen times as many atoms as an equal mass of oxygen; therefore, when compared weight for weight, hydrogen has a specific heat sixteen times greater than that of oxygen.

Or, in general, comparing equal weights, the specific heat of an elementary substance is inversely proportional to its atomic weight. (See *Calorimeter.*)

Heat, Specific ——— of Electricity.—(See *Specific Heat of Electricity.*)

Heat Unit, English, or British Thermal Unit.—The quantity of heat required to raise the temperature of one pound of water 1° F.

This heat unit represents an amount of work equivalent to 772 foot-pounds. (See *Mechanical Equivalent of Heat.*)

1 Foot Pound = 13,562,600 *Ergs.* (See *Erg.*)

Heat Unit, or Calorie.—The quantity of heat required to raise the temperature of one gramme of water 1° C.

The calorie is sometimes taken as the amount of heat required to raise the temperature of 1,000 grammes of water 1° C. These are termed, respectively, the *Small Calorie* and the *Large Calorie.* (See *Calorie.*)

Heat Unit, or Joule.—The quantity of heat developed by the passage of a current of one ampère through a resistance of one *ohm*. (See *Joule.*)

1 Joule = .24 Calorie.

1 Foot Pound = 1.356 Joule.

Heater, Electric ——— —A device for the conversion of electricity into heat for the purposes of artificial heating.

Electric heaters consist essentially of coils or circuits of some refractory substance of high resistance, through which the current is passed. These coils or circuits are surrounded by air or finely divided solids, and placed inside metallic boxes, or radiators, which throw off or radiate the heat produced.

When employed for the heating of liquids the coils are placed directly in the liquid to be heated, or are surrounded by radiating boxes that are placed in the liquid.

Heating Effects of Currents.—(See *Heat, Electric. Calorimeter, Electric. Joule's Laws.*)

Hecto (as a prefix.)—One hundred times.

Helices, Sinistrorsal and Dextrorsal ——— —Coils of wire so wrapped or wound that when traversed by an electric current they acquire all the properties of magnets. (See *Solenoids, Sinistrorsal and Dextrorsal.*)

Heliograph.—An instrument for telegraphic communication by means of flashes of light, which represent the dots and dashes of the *Morse alphabet*, or the movements of the needle of the *needle telegraph* to the right or left. (See *Alphabet Telegraphic.*)

The flashes of light are thrown from the surface of a plane mirror. Motions to the right or left may be used to distinguish between the dots and dashes, or the same purpose may be effected by the relative durations of the flashes of light, or by the intervals between successive flashes.

Similar telegraphic communication has been carried on between steamers during foggy weather by means of their fog horns, or between locomotives, by their steam whistles.

Hermetical Seal.—Such a sealing of a vessel, designed to hold a vacuum, or gaseous atmosphere under pressures greater or less than that of the atmosphere, as will prevent either the entrance of the external atmosphere into the vessel, or the escape of the contained gas into the atmosphere.

Hermetical sealing may be accomplished either by the use of suitable cements, or by the direct fusion of the walls of the containing vessel.

Heterostatic.—A term applied by Sir William Thomson to an electrometer in which the electrification is measured by determining the attraction exerted by the charge to be measured and that of an opposite charge imparted to the instrument by a source independent of the charge to be measured.

This term distinguishes this electrometer from an *idiostatic instrument*, or one in which the measurement is effected by determining the repulsion between the charge to be measured and that of a charge of the same sign imparted to the instrument from an independent source. (See *Electrometer.*)

Hicks' Automatic Button Repeater.—(See *Repeater, Telegraphic*).

Holders for Brushes of Dynamo Electric Machines.—A device for holding the collecting brushes of a dynamo-electric machine. (See *Dynamo-Electric Machines.*)

Holders for Carbons of Arc Lamp.—(See *Lamp, Electric Arc.*)

Holders for Safety Fuse.—(See *Fuse, Safety.*)

Hood for Electric Lamp.—A hood provided for the double purpose of protecting the body of an electric lamp from rain or sun, and for throwing its light in a general downward direction.

Hoods for arc lamps are generally conical in shape.

Horizontal Component of Magnetism. (See *Component, Horizontal, of Earth's Magnetism.*)

Horns, Following and Leading, —— of Dynamo-Electric Machines.—The edges or terminals of the pole-pieces of a dynamo-electric machine *from* or *towards* which the armature is carried during its rotation.

According to S. P. Thompson, the *following horns, b, d,* Fig. 231, are those *towards* which the armature is carried; the *leading horns, a, c,* those *from* which it is carried.

As the change in the magnetic intensity is more sudden when the armature is moved *from* the pole pieces, and *least* when moved *towards* them, it is clear that the leading horns in a dynamo-electric machine, and the following horns in an electric motor, become heated during rotation by the production of *eddy currents.* (See *Currents, Eddy. Dynamo Electric Machines.*)

Horse Power.—A commercial unit for *rate of doing work.*

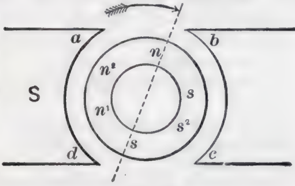


Fig. 231.

A rate of doing work equal to 33,000 pounds raised one foot per minute, or 550 pounds raised one foot per second.

A careful distinction must be drawn between *work* and *power.* The same *amount of work* is done in raising one pound through ten feet, whether it be done in one minute or in one hour. The *power expended,* or the *rate of doing work* is, however, quite different, being in the former case sixty times greater than in the latter.

Horse-Power, Electric ————.—Such a rate of doing electric work as is equal to 33,000 foot-pounds per minute, or 550 foot-pounds per second.

Just as one pound of water raised through a vertical distance of one foot requires the expenditure of a foot-pound of energy, so one *coulomb* of electricity acting through the *differ-*

ence of potential of one *volt* requires a certain amount of work to be done on it. (See *Coulomb. Volt. Potential.*)

This amount is called a *volt-coulomb* or *joule* and, measured in *foot-pounds,* is equal to .737324 foot-pounds. The *volt-coulomb,* or the *joule,* is therefore the *unit of electric work,* just as the *foot-pound* is the unit of *mechanical work.*

The electric work of any circuit is equal to the product of the *volts* by the *coulombs.*

If we determine the *rate per second at which the coulombs pass,* and multiply this product by the volts, we have a quantity which represents the electrical *power,* or *rate of doing electrical work.* But one *ampère* is equal to *one coulomb per second;* therefore, if we multiply the current in ampères by the difference of potential in *volts,* the product is equal to the *electrical power* or rate of doing *electrical work.*

The product of an *ampère* by a *volt* is called a *volt-ampère,* or a *watt.*

One Watt = .0013406 Horse-power, or

One Horse-power = 745.941 Watts.

Therefore the Electrical Horse-power $= \dfrac{C\ E}{746}$,

where C = the current in ampères, and E = the difference of potential in volts.

Horseshoe Magnet.—A magnetized bar of steel or iron bent in the form of a horseshoe, or letter U.

A compound horseshoe magnet is shown in Fig. 232. It consists of separately magnetized plates placed with their *similar* poles together.

A horseshoe magnet possesses greater portative power than a straight bar magnet. (See *Portative Power.*)

(1) Because its opposite poles are nearer together, and

(2) Because the magnetic resistance of its circuit is less, the lines of magnetic force closing through the armature, and thus concentrating the magnetic attraction on the armature.

Electro-magnets are generally made of the horseshoe shape.

Human Body, Electric Resistance of —— —The electric resistance offered by the human body.

Accurate data concerning the resistance of the human body are yet to be obtained.

When the electrodes of any source are applied to the skin, the resistance will necessarily vary with the *size and position* of the contacts, the *nature* of the contacts, the *condition* both of the *skin* and the *contacts*, whether dry or moist, and the pathological or other condition of the portion acted on.

The chief resistance offered by the human body to the passage of an electric current is the *skin*. It may be regarded as a protective covering so far as electric currents are concerned.

The body is composed, generally speaking, of solids and liquids. The liquids offer paths of less resistance than the solids. The *blood* and *nerves* are probably the best conducting media in the body. The *muscles* offer a fair conducting path from the quantity of saline fluids they contain.

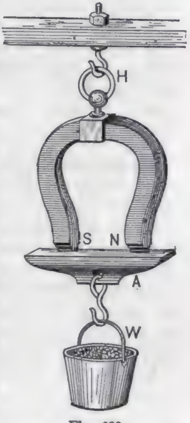


Fig. 232.

Since the human body, like that of all animals, is itself a source of electric currents, it is possible that the passage through it of a current generated from without, would of itself greatly alter its electric resistance.

Wolfenden found the resistance in fifty healthy persons, measured under exactly similar conditions, to vary from 4,000 to 5,000 ohms.

Certain diseased conditions of the body appear to cause a marked variation in what may perhaps be regarded as a normal electric resistance. Charcot made measurements in which

it appears that the resistance fell below the normal in certain *cardiac* affections, and in *Graves' Disease,* Wolfenden corroborates this, and in eighteen cases of undoubted Graves' Disease the resistance was but 500 to 1,500 ohms. In eight of these it was less than 1,000 ohms. In ordinary *goitre,* unlike Graves' Disease (*Exophthalmic Goitre*), no variation of the resistance was found. In a case of *malignant thyroid* it was as high as 8,000 ohms.

In some cases of *hemiplegia,* it varied from 1,300 to 4,000 ohms. In some of *epilepsy,* from 1,000 to 4,000. In three cases of *cerebral softening,* the resistance was about 3,000 ohms and in one case of *paraplegia,* it was 6,500 ohms, and in one case of *chorea* (adult), 350 ohms. (*Wolfenden.*)

Hydro-Electric Machine, Armstrong's —— —A machine for the development of electricity by the friction of condensed steam passing over a water surface.

Steam generated in a suitable boiler, Fig. 233, which is insulated, is allowed to escape through a tortuous nozzle, from a series of apertures opposite a pointed comb, attached to an insulated conductor. The cooling of the steam during its passage through a flat box, termed the *cooling box,* connected with the nozzles, causes a partial condensation, so that the box always contains a small quantity of water.

The friction of the drops of water against the orifice and possibly their friction against the water surface itself are the cause of the electricity.

A conductor connected with the pointed comb furnishes positive electricity. The boiler furnishes negative electricity. The hydro-electric machine is not a very economical source of electricity, and is only employed for experimental purposes. It was discovered accidentally through a shock given to an engineer, who placed his hand in a jet of steam escaping from a leaking boiler he was endeavoring to mend. The causes were first studied by Mr., now Sir Wm., Armstrong, who, in 1840, devised the apparatus just described.

Hydrometer or Areometer.—An apparatus for determining the specific gravity of liquids. (See *Areometer.*)

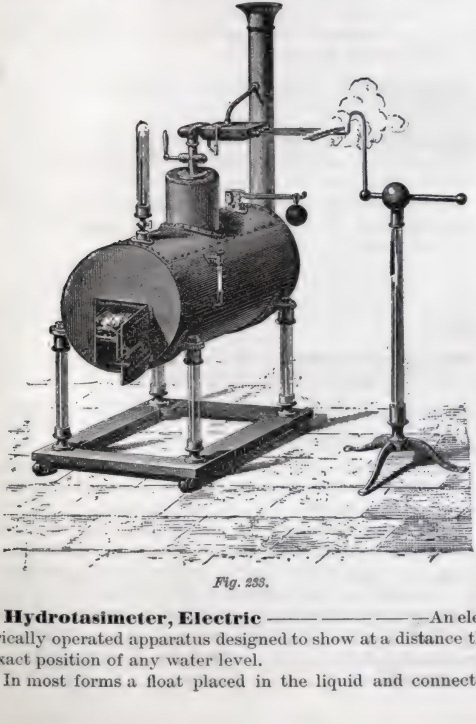


Fig. 233.

Hydrotasimeter, Electric ———— ———— ——— —An electrically operated apparatus designed to show at a distance the exact position of any water level.

In most forms a float placed in the liquid and connected

with an electric circuit, breaks this circuit, and, at intervals, sends positive impulses into the line when rising, and negative impulses when falling. These are registered by means of an index moved by a step-by-step motion, positive currents moving it in one direction, and negative currents moving it in the opposite direction.

Hygrometer.—An apparatus for determining the amount of moisture in the air.

Hypothesis.—A provisional assumption of facts or causes, the real nature of which is unknown, made for the purpose of studying the effects of such causes.

A *theory* is a more or less accurate expression of some physical truth which has been deduced from independently derived laws and principles.

Our notions concerning the causes of electricity have, in reality, only reached the stage of *hypotheses;* they cannot yet be properly considered as having attained the dignity of *theories.*

Hypothesis, Double Fluid Electric ——.—(See *Double Fluid Electric Hypothesis.*)

Hypothesis, Single Fluid Electric——.—(See *Single Fluid Electric Hypothesis.*)

Hypsometer.—An apparatus for determining the elevation of a mountain or other place, by obtaining the exact temperature at which water boils at such elevation.

The use of a thermometer to measure the height of a mountain or other elevation is based on the fact that a given decrease in the temperature of the boiling point of water invariably attends a given decrease in the atmospheric pressure. Therefore, as the observer goes further above the level of the sea, the boiling point of water becomes lower, and from this decrease, the height of the mountain or other elevation may be calculated.

Idio-Electrics.—A name formerly applied to such bodies as amber, resins, glass, etc., which are readily electrified by friction and which were then supposed to be electric in themselves.

This distinction was based on an erroneous conception, and the word is now obsolete.

Idiostatic.—A term employed by Sir Wm. Thomson, to designate an electrometer in which the measurement is effected by determining the repulsion between the charge to be measured and that of a charge of the same sign imparted to the instrument from an independent source. (See *Heterostatic.*)

Igniter, Jablochkoff ——— —A small strip of carbon, or carbonaceous paste of readily ignitable material, placed at the free ends of the parallel carbons of a Jablochkoff candle, for the establishment of the arc on the passage of the current.

The *igniter* is necessary in the Jablochkoff electric candle, since the parallel carbons are rigidly kept at a constant distance apart by the insulating material placed between them, and cannot therefore be moved together as in the case of the ordinary lamp. (See *Candle, Jablochkoff.*)

Ignition, Electric ——— —The ignition of a combustible material by heat of electric origin.

The electric ignition of wires is generally accomplished by electric *incandescence.* Ignition may be accomplished by the heat of the voltaic arc. (See *Heat, Electric. Furnace, Electric.*)

The ignition of combustible gases is accomplished by the heat of the electric spark. (See *Burner, Automatic Electric.*)

Illumination, Artificial ——— —The employment of artificial sources of light to render objects visible.

A good artificial illuminant should possess the following properties, viz.:

(1) It should give a *general or uniforn illumination* as distinguished from sharply marked regions of light and shadow.

To this end, a number of small lights well distributed are preferable to a few large lights.

(2) It should give a *steady light, uniform in its brilliancy,* as distinguished from a flickering, unsteady light. Sudden changes in the intensity of a light injure the eyes and prevent distinct vision.

(3) It should be *economical,* or not cost too much to produce.

(4) It should be *safe,* or not likely to cause loss of life or property. To this intent it should, if possible, be inclosed in or surrounded by a lantern or chamber of some incombustible material, and should preferably be lighted at a distance.

(5) It should not give off *noxious fumes or vapors,* when in use, nor should it *unduly heat the air* of the space it illumines.

(6) It should be *reliable,* or not apt to be unexpectedly extingished when once lighted.

The claims of the electric incandescent lamp as a cheap safe, reliable and steady, artificial illuminant, will be evident if these points are examined seriatim, viz.:

(1) The incandescent light is capable of great sub-division, and can therefore produce a uniform illumination.

(2) It is steady and free from sudden changes in its intensity.

(3) It compares favorably in point of economy with coal oil or gas.

(4) It is safer than any known illuminant, since it can be entirely inclosed and can be lighted from a distance, or at the burner, without the use of the dangerous friction match.

The leads, however, must be carefully insulated and protected by *safety fuses.* (See *Fuse, Safety.*)

(5) It gives off no gases, and produces far less heat than a gas burner of the same candle power.

It perplexes many people to understand why the incandescent electric light should not heat the air of a room as much as a gas light, since it is quite as hot as the gas light. It must be remembered, however, that a gas burner, when lighted, not only permits the same quantity of gas to enter

the room which would pass if the gas were simply turned on and not lighted, but that this bulk of gas is still given off, and is even considerably increased, by the combination of the illuminating gas with the oxygen of the atmosphere, and which moreover, it is given off as highly heated gases. Such gases are entirely absent in the incandescent electric light, and consequently its power of heating the surrounding air is much less than that of gas lights.

(6) It is quite reliable and will continue to burn as long as the current is supplied to it.

Illumination, Light House —— Electric.—(See *Light House Illumination, Electric*).

Illumination, Unit of —— —A standard of illumination proposed by Preece, equal to the illumination on a surface such as a street, given by a standard candle at the distance of 12.7 inches.

According to Preece, the illumination for the average streets of London, where gas is employed, is equal to about one-tenth this standard, in the neighborhood of a gas lamp, and about one-fiftieth, in the middle space between two lamps.

The term, *unit of illumination*, in place of the *intensity of light*, was proposed by Preece, in order to avoid the very great difficulty in determining the intensity of a light in a street or space where there were a number of luminous sources, and where the directions of incidence of the different lights vary so greatly.

A carcel standard at the distance of a metre will illumine a surface to the same intensity of illumination as a standard candle at the distance of 12.7 inches.

Images, Electric —— —A term sometimes applied to the charge produced in a neighboring surface by induction from a known charge.

A positive charge produces by induction, in a flat metallic surface near it, a negative charge which is distributed with

varying density over the surface, but acts electrically as would an equal quantity of negative electricity placed back of the plate, at the same distance the positive charge is in front of it. The correspondence of this charge with the image of an object seen in a plane mirror has led to the term electrical image.

Maxwell defines electric image as follows: "An electric image is an electrified point, or system of points, on one side of a surface, which would produce on the other side of that surface the same electrical action which the actual electrification of that surface really does produce."

Imponderable.—That which possesses no weight.

A term formerly applied to the luminiferous or universal ether, but now generally abandoned. It is very questionable whether it is possible for any form of matter to be actually imponderable, or to possess no attraction for other matter

An imponderable fluid, as for example the universal ether, as the term is now generally employed, is a fluid whose weight is comparatively small and insignificant, and not a fluid, an indefinite quantity of which would be entirely devoid of weight.

Incandescence, Electric ——————.—The electric heating of a substance, generally a solid, to luminosity.

Electric incandescence of solid substances differs from ordinary incandescence, in the fact that unless the substance is electrically homogeneous throughout, the temperature is not uniform in all parts, but is highest in those portions where the resistance is highest and the radiation smallest. The deposition of carbon in and on a carbon conductor by the *flashing process* is quite different as performed by electrical incandescence, than it would be if the carbons were heated by ordinary furnace or other heat. (See *Flashing of Carbons.*)

Inclination Compass, or Inclinometer.—A magnetic needle so arranged as to readily permit the measurement

of the magnetic dip at any place. (See *Dipping Circle or Inclination Compass.*)

Inclination, Magnetic —— —(See *Magnetic Inclination.*)

Inclination Map or Chart.—A chart or map on which lines are drawn showing the lines of equal dip or inclination, or the *isoclinic lines.*

An *inclination chart* is shown in Fig 234.

It will be seen that the magnetic equator, or line of no dip, does not correspond with the geographical equator, being generally north of the equator in the eastern hemisphere, and south of it in the western. The figures attached to the lines indicate the value of the angle of dip.

Inclination or Dip of Magnetic Needle.—The deviation of an evenly weighted magnetic needle from a horizontal position.

The direction of a magnetic needle in all parts of the earth, except at the magnetic equator, differs from a level or horizontal position. One of its ends inclines or dips towards the ground. (See *Dip, Magnetic. Dipping Needle.*)

India Rubber.—A resinous substance obtained from the milky juices of several tropical trees.

India rubber is quite elastic and possesses high powers of electric insulation. When *vulcanized* or combined with sulphur, it still retains its powers of electric insulation in a high degree. In this state it is readily electrified by friction. (See *Caoutchouc*).

Indicating Bell.—(See *Bell, Indicating.*)

Indicators, Electric—— —Various devices, generally operated by the deflection of a magnetic needle, or the ringing of a bell, or both, for indicating at some distant point the condition of an electric circuit, the strength of current that is flowing through it, the height of water or other liquid, the pressure on a boiler, the temperature, the speed of an engine

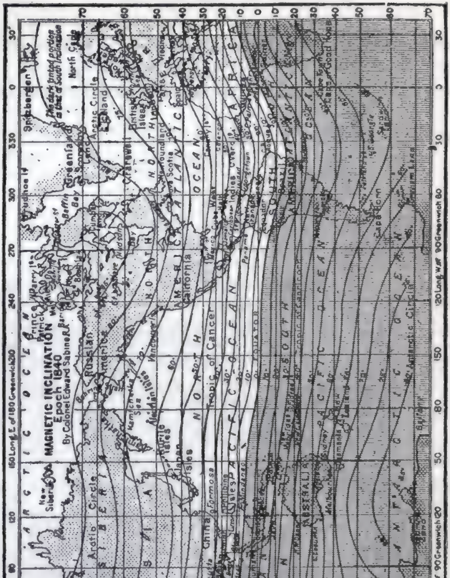

MAGNETIC INCLINATION
Epoch 1840
By Colonel Edward Sabine R.A.

Fig. 234.

or line of shafting, the working of a machine, or other similar events or occurrences.

Indicators are of various forms. They are generally electro-magnetic in character.

Indicators, Electric Circuit ——— — Various devices, generally in the form of vertical galvanometers, employed to indicate the presence and direction of a current in a circuit, and often to roughly measure its strength. (See *Galvanometer, Vertical.*)

Induced Current, Direct Induced Current.—(See *Current, Extra.*)

Induced Current, Reverse Induced Current.—(See *Current, Extra.*)

Induction Balance, Hughes' ——— —(See *Balance, Induction, Hughes'.*)

Induction, Dynamo Electric ——— —(See *Induction, Electro-Dynamic.*)

Induction, Electro-Dynamic ——— —Electro motive forces set up by induction in conductors which are either actually or practically moved so as to cut the lines of magnetic force.

These electro-motive forces, when permitted to act or neutralize themselves, produce a current.

Electro-dynamic induction occurs only in a magnetic field, the intensity of which is either increasing or decreasing. It may be produced in the following ways, viz.:

(1) By the use of an inducing field of varying magnetic intensity.

Varying the strength of the current and consequently the intensity of its magnetic field, will produce an induction of the circuit on itself, or a *self-induction,* and will result in *extra currents,* which are in the opposite direction on closing and in the same direction on opening the circuit; or it will produce induction in neighboring conductors which are

within the field of the inducing current. (See *Self-Induction. Mutual Induction. Currents, Extra.*)

(2) By using an inducing field of practically unvarying intensity, and varying the number of lines of magnetic force that pass through a conductor, by moving the conductor through the inducing field so as to cut its lines of force.

Or, the conductor remaining fixed in position, the inducing field is moved past the conductor by moving the electro-magnet, or electric circuit, or permanent magnet producing the field.

Electro-dynamic induction, therefore, includes.

(1) Self-induction.

(2) Mutual Induction, or, as it is sometimes called, Voltaic or Current Induction.

(3) Electro-Magnetic Induction, or Dynamo-Electric Induction.

(4) Magneto-Electric Induction.

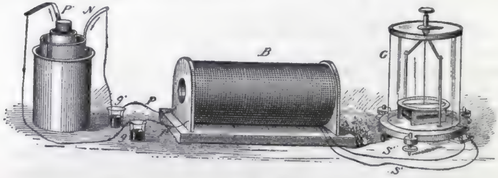


Fig. 235.

The coil B, Fig. 235, consists of two parallel coils of insulated wire, the terminals of one of which, called the *primary coil*, are connected with the battery cell P N, and those of the other, called the *secondary* coil, with the galvanometer G.

Under these circumstances it is found:

(1) That at the moment of closing the circuit, through the primary coil, a momentary current is produced in the secondary coil in a *direction opposite to that of the current through*

the primary, as is shown by the direction of deflection of the needle of the galvanometer.

(2) At the moment of breaking the circuit through the primary coil an induced current is produced in the secondary coil in the *same direction as that flowing through the primary coil.*

(3) These induced currents are momentary, and only continue in the secondary while the intensity of the current in the primary is varying, *i.e.*, while variations are occurring in the strength of the magnetic field in which the secondary coil is placed.

If, for instance, when the current is established in the primary coil, and no current exists in the secondary, the intensity of the current in the primary be varied by establishing a *shunt circuit* across the battery terminals, as by placing a short wire *d*, Fig. 236, in the mercury cups *g*, *g*, thus decreasing the intensity of the current in the primary, an induced current will be set up in the secondary circuit in the same direction as the primary current.

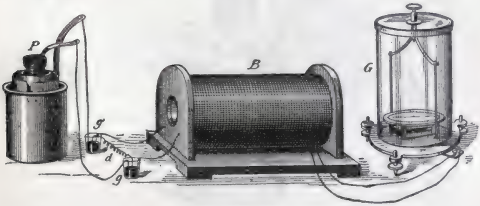


Fig. 236.

From all of these phenomena we see that an *increase* of current in a conductor produces in a neighboring conductor an *induced inverse* current, or one in the *opposite direction to the inducing current,* while a *decrease* of such current pro-

duces a *direct induced current*, or one in the *same direction as the inducing current*.

If the induction coil be made, as in Fig. 237, with its primary coil movable into and out of the secondary coil, then the following phenomena will occur:

(1) When the primary coil is moved towards the secondary coil an *inverse* current is induced in the secondary, and,

(2) When the primary coil is moved away from the secondary coil a *direct* current is induced in the secondary.

The movements of permanent magnets towards or from a coil will also produce an induced current.

If, for example, the apparatus be arranged, as in Fig. 238, then:

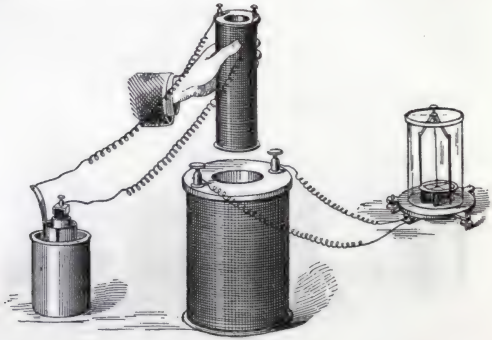


Fig. 237.

(1) A motion of the magnet towards the coil produces an induced current in the coil in one direction, and

(2) Its motion away from the magnet produces an induced current in the coil in the opposite direction.

These induced currents are respectively *inverse* and *direct* as compared with the direction of the ampèrian currents which are assumed to produce the magnetic poles of permanent magnets, or of the currents that actually produce electro magnets. (See *Magnetism, Ampère's Theory.*)

Induction, Electro-Magnetic ——— —(See *Induction Electro-Dynamic.*)

These facts may be expressed by the following laws :

(1) Any *decrease* in the number of lines of force which pass through a circuit produces a *direct* current in that circuit, while any *increase* in the number of such lines of force which pass through any circuit produces an *inverse* current in that circuit.

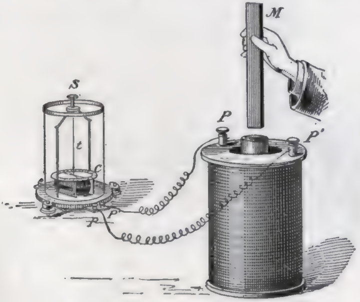


Fig. 238.

(2) The induced current has an intensity, or more correctly, the *differences* of *potential* produced are proportional to the *rate* of *increase* or *decrease* of lines of force passing through the circuit.

Any conductor therefore, when moved through a magnetic field so as to cut the lines of magnetic force, will have a current produced in it by induction.

A simple but effective manner of remembering the direction of such currents is that proposed by Fleming.

If the hand be held with the fingers extended, as in Fig. 239, and the direction of the *fore finger* represent the positive direction of the lines of force, *i. e.*, those coming out of the N. pole of a magnet, then, if a wire or other conductor be moved in the direction in which the *thumb* points, so as to cut these lines of force at right angles, that is if the conductor have its length moved directly across these lines, it will have an induced current developed in it in the direction in which the *middle finger* points. (See *Direction of Lines of Force*).

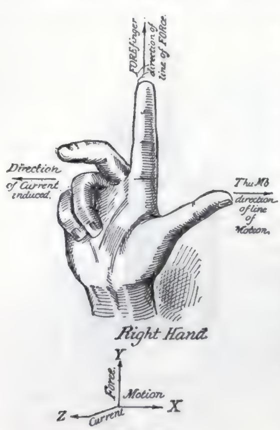


Fig. 239.

Or, the same thing can, perhaps, be even more readily remembered by cutting a piece of paper in the shape shown in Fig. 240, marking it as shown, and then bending the arm P, upwards at the dotted line, so as to form three axes at right angles to one another.

As has been already remarked, a *difference of potential* is produced by the motion of a conductor through a magnetic field so as to cut its lines of force, and not a current.

It can be shown that in order to generate a difference of potential of *one volt*, 100,000,000 C. G. S. lines of force must be cut per second.

In electro-magnetic induction the induced current is produced by the energy absorbed by moving the conductor through

the field. Lenz has shown that in all cases of electro-magnetic induction, produced by the movement either of the circuit or of the magnet, the current induced in the circuit is in such a direction as to produce a magnet pole which would tend to oppose the motion.

For mutual attraction and repulsion of currents see *Electro-Dynamics*.

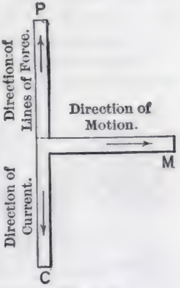


Fig. 240.

Induction, Electrostatic —— —— —The production of an electric charge in a conductor brought into an *electrostatic field*.

If the insulated conductor A B, Fig. 241, be brought into the positive electrostatic field of the insulated conductor C, then,

(1) A charge will be produced on A B, as will be indicated by the divergence of the pith balls.

(2) This charge is negative at the end A, nearest C, and positive at the end C, furthest from B, as can be shown by an *electroscope*. (See *Electroscope*.)

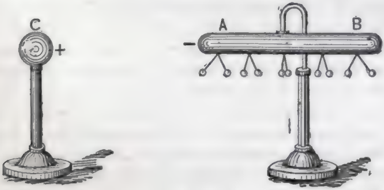


Fig. 241.

(3) The charges at A and B, are equal to each other; for, if the conductor A B, be removed from the field of C, without touching it, the opposite charges completely neutralize each other.

(4) If, however, the conductor A B, be touched at any place by a conductor connected with the earth, it will lose its positive charge, and will remain negatively charged when removed from the field of C. It is in this manner that the *electrophorus* is charged. (See *Electrophorus.*)

(5) The amount of the charges produced in the conductor, A B, can never be greater than that in the inducing body C. That is to say, the negative electricity at A, may be sufficient in amount to neutralize the positive charge on C, if allowed to do so. In point of fact the charge induced is less in amount than the inducing charge, according to the distance between C and A, and the nature and condition of the medium which separates them.

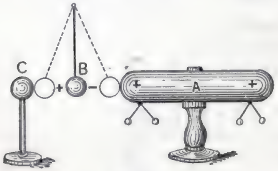


Fig. 242.

The attractions of light bodies by charged surfaces is due to the opposite charge produced on those parts of the light bodies that are nearest the charged body.

The pith ball B, Fig. 242, suspended by a silk thread between an insulated positively charged conductor A, and the uninsulated conductor C, will receive by induction a negative charge on the side nearest to A, and a positive charge on the side nearest to C. It is therefore attracted to A, where, receiving a positive charge, it is repelled to C, where it is discharged and again assumes a vertical position. Induction again occurs, and consequent attraction and repulsion. These movements follow one another so long as a sufficient charge remains in A.

Induction Coils.—Parallel coils of insulated wire employed for the production of currents by *electro-magnetic induction.* (See *Induction, Electro-Magnetic.*)

A rapidly interrupted battery current sent through a coil of wire called the *primary coil*, induces intermittent currents in a coil of wire called the *secondary coil.*

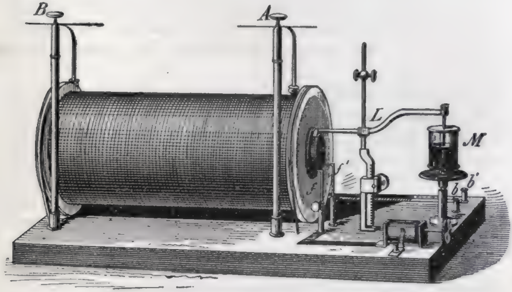


Fig. 243.

As heretofore made, the primary coil consists of a few turns of a thick wire, and the secondary coil of many turns, often thousands, of fine wire. Such coils are generally called *Ruhmkorff Coils*, from the name of a celebrated manufacturer of them.

In the form of Ruhmkorff coil, shown in Fig. 243, the primary wire is wound on a core formed of soft iron wires, and its ends brought out as shown at *f*, *f'*. The fine wire is wrapped around an insulated cylinder of vulcanite, or glass, surrounding the primary coil. This wire is very thin, and in some coils is over one hundred miles in length.

The ends of the secondary coil are connected to the insulated pillars A and B.

The primary current is rapidly broken by means of a mercury break, shown at L, and M.

The *commutator*, shown to the right and front of the base, is provided for the purpose of cutting off the current through the primary, or for changing its direction. When a battery which produces a comparatively large current of but a few volts electro-motive force, is connected with the primary, and its current rapidly interrupted, a torrent of sparks will pass between A and B, having an electro-motive force of many thousands of volts.

In such cases. excepting losses during conversion, the energy in the primary current, or C E, is equal to the energy in the secondary current, or C′ E′. As much therefore as E′, the electro-motive force of the secondary current exceeds E, the electro-motive force of the primary current, the current strength C′, of the secondary will be less than the current strength C, of the primary. (See *Converter, or Transformer.*)

Fig. 244, shows diagramatically the arrangement and connection of the different parts of an induction coil.

The core I, I′ consists of a bundle of soft iron wires, each of which is covered with a thin insulating layer of varnish or oxide. A primary wire P, P, consisting of a few turns of comparatively thick wire is wound around the core, and a greater length of thin wire S, S, is wound upon the primary. This is called the secondary. So as not to confuse the details of the figure it is represented as a few turns.

The ends of the battery B are connected to the primary wire, through the automatic interrupter, in the manner shown. It will be seen that the attraction of the core I I′, for the vibrating armature H, will break contact at the point *o*, and cause a continued interruption of the battery current.

The condenser C, C′, is connected as shown. It acts to diminish the sparking at the contact points on breaking contact, and thus, by making the battery current more sudden, to consequently make its inductive action greater.

Induction Coils, Inverted —— —— Converters. Transformers.—An inverted induction coil is an induction coil in which the *primary coil* is made of a long, thin wire, and the *secondary coil* of a *short, thick* wire.

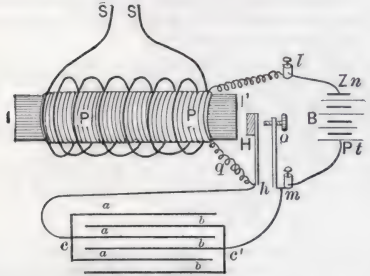


Fig. 244.

By the use of an inverted coil, a current of high electromotive force and comparatively small current strength, *i. e.*, but of few *ampères*, is *converted* or *transformed* into a current of comparatively small electromotive force and large current strength. For the advantages of this see *System of Distribution by Alternating Currents.*

Inverted induction coils are called *converters* or *transformers.* (*Converter or Transformer.*)

Induction, Lateral ——— —(See *Lateral Induction.*)

Induction, Magnetic ——— —The production of magnetism in a magnetizable substance by bringing it into a magnetic field.

When a magnetizable body is brought into a magnetic field the following phenomena occur, viz.:

(1) The lines of magnetic force pass through the body and are condensed upon it. (See *Field, Magnetic. Paramagnetic.*)

(2) If the body is free to move around an axis, but not bodily towards the magnet pole, it will come to rest with its greatest extent or length in the direction of the lines of force ; *i. e.*, in the direction in which it will offer the least resistance to the lines of force that thread through it.

(3) The body will therefore become a magnet, its south pole being situated where the lines of force enter it, and its north pole where they pass out from it.

(4) The intensity of the induced magnetism will depend on the number of lines of force that pass through it.

(5) The direction of the *axis of magnetism* will depend on the directions in which the lines of force thread through the body. (See *Axis of Magnetism*).

If a bar of iron N, S, Fig. 245, be brought near the magnetized bar, N, S, poles will be produced in it by induction, as may be shown by throwing iron filings on it.

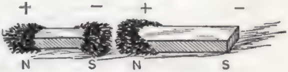


Fig. 245.

Since the nearer the body to be magnetized is brought to the magnetizing pole, the greater will be the number of lines of force that thread through it, the greater will be the intensity of its induced magnetism. This will be greatest when the two actually touch each other.

The production of magnetism therefore by contact or touch is only a special case of magnetization by induction.

The attraction of a magnetizable body by a magnet pole, is caused by the mutual attraction which exists between the unlike pole produced by induction in the parts of the piece of iron nearest the attracting magnet pole. This, it will be seen, is the same as the attraction caused by an electric charge.

Induction, Magneto Electric —— —(See *Induction, Electro Dynamic.*)

Induction, Mutual ——— —Induction produced by two neighboring circuits on one another by the mutual interaction of their magnetic fields. (See *Currents, Extra.*)

Induction, Self ———— —Induction produced in a circuit at the moment of starting or stopping the currents therein, by the induction of the current on itself. (See *Current, Extra.*)

Induction Top.—A top consisting of an iron disc supported on a vertical axis, which, when spun before the poles of a steel magnet assumes an inclined position, through the influence of the currents induced in the disc.

The top maintains the inclined position so long only as the strength of the induced currents is sufficiently great; that is while speed of rotation is sufficiently great.

Induction, Tubes of ——— —(See *Force, Tubes of, or Tubes of Induction.*)

Inductive Capacity, Specific ———— —(See *Capacity, Specific Inductive.*)

Inductometer, Differential ———— —An apparatus for measuring by means of a galvanometer the momentary currents produced by the discharge of a cable.

Currents produced by the discharge of a cable are of so short a duration that they do not produce much effect on a galvanometer needle.

The inductive charge in a cable, or the quantity of electricity produced in it by induction, is

(1) Directly as the electromotive force of the charging battery.

(2) Inversely as the square root of the thickness of the coating of gutta-percha or other insulating material between the conducting wires and the metallic sheathing, and

(3) Directly as the square root of the diameter of the copper wire of the conductor. In order to cause the cable discharge to more thoroughly affect the galvanometer needle, Mr.

Latimer Clark employed a differential instrument with a large battery, and three reversing keys, by means of which he gave a rapid successsion of charges to the cable. He called the instrument a *Differential Inductometer.*

Inductophone.—A device suggested by Mr. Willoughby Smith for obtaining electric communication between trains in motion and fixed stations by means of the induction currents developed in a spiral of wire fixed on the moving engine, in its motion past spirals on the line, into which intermittent currents are passed.

The spiral on the engine is placed in the circuit of a telephone. (See *Telegraphy, Inductive.*)

Inductorium.—A name sometimes applied to a *Ruhmkorff induction coil.* (See *Induction Coils.*)

Inertia.—The inability of a body to change its condition of rest or motion, unless some force acts on it.

The inertia of matter is expressed in Newton's first law of motion, as follows :

"Every body tends to preserve its state of rest or of uniform motion in a straight line, unless in so far as it is acted on by an impressed force."

All matter possesses inertia.

Inertia, Magnetic —— or Lag.—The inability of a magnet core to instantly lose or acquire magnetism.

The magnet core tends to continue in the magnetic state in which it was last placed.

To decrease the magnetic inertia the strength of the magnetizing current is *increased* and the length of the iron core *decreased.* The iron should also be quite soft. (See *Coercive Force. Lag, Magnetic.*)

Infinity Plug.—A plug, in a box of resistance coils, in which the two pieces of brass it connects are not connected by any resistance coil and which, therefore, leaves on unplugging, an open circuit or an infinite resistance.

Ink-Writer, Telegraphic, —— —— or Recorder. (See *Balance, Wheatstone's Electric, Box, Form of.*)—A device employed for recording the dots and dashes of a telegraphic message in ink on a fillet or strip of paper.

Insolation, Electric.—(See *Sun Stroke, Electric.*)

Installation.—A term embracing the entire electric plant and its accessories required to perform any specified work.

Insulating Cements.—(See *Cements, Insulating.*)

Insulating Materials.—Non-conducting substances which surround a conductor, in order that it may either retain an electric charge, or permit the passage of an electric current through the conductor without sensible leakage.

Various gases, liquids, or solids may be employed as insulators. A high vacuum affords the best known insulation.

Insulating Stool.—A stool provided with insulating legs, on which a person, or other body, may be placed in order to receive an electric charge.

Insulating Tape.—(See *Tape, Insulating.*)

Insulating Varnish.—(See *Varnish, Insulating.*)

Insulators, Telegraphic or Telephonic. —— — Non-conducting supports, by means of which telegraphic, telephonic, electric light wires, or other wires are attached to the objects by which they are supported.

The insulators are generally made of glass, earthenware, porcelain, or hard rubber, and assume a variety of forms, some of which are shown in Figs. 246, 247, and 248. Of whatever material they are made, it is necessary that the surface on which the wire rests, or around which it is wrapped, should be smooth so as to avoid abrasion either of its insulating covering or of the wire itself.

Two things are to be considered in the selection of an insulator, viz.:

(1) The insulating power of the material of which it is composed, so as to reduce the *leakage* as much as possible. (See *Electric Leakage*). And,

Fig. 246.

(2) The tensile strength of the material, so that in case of heavy wires no breaks may result from the fracture of the insulator.

Intensity of Current.—A term sometimes employed to indicate current strength. (See *Ampère.*)

Intensity of Field.—The strength of a field as measured by the number of lines of force that pass through it per unit of area of cross section. (See *Field, Electrostatic. Field, Magnetic.*)

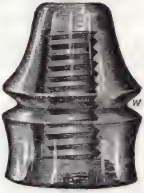


Fig. 247.

Intensity of Light.—The brilliancy or illuminating power of a light as measured by a *photometer* in *standard candles.* (See *Photometer.*)

Intensity of Magnetization, or Magnetic Density.—The strength of magnetism as measured by the number of lines of magnetic force that pass through a unit of area of cross section of the magnet, *i. e.*, a section taken at right angles to the lines of force. (See *Magnetic Density.*)

Fig. 248.

Interlocking Apparatus.—Devices for mechanically operating railroad switches, and semaphore signals for indicating the position of such switches, from a distant signal tower, by means of a system of interlocking levers, so constructed that the signals and the switches are interlocked, so as to render it impossible, after a route has once been set up and a signal given, to clear a signal for a route that would conflict with the one previously set up.

Intermittent Earth.—(See *Earths.*)

Interrupter.—Any device for interrupting or breaking a circuit.

Interrupter, Automatic ——— —(See *Automatic Contact Breaker.*)

Interrupter, Tuning Fork or Reed ——————— — An interrupter in which the makes and breaks are caused to follow one another by the vibrations of a tuning fork or reed.

The tuning fork or reed is maintained in vibration by any suitable means. Such interrupters are applied to various uses. Synchronous multiplex telegraphy is an example of such uses.

Inverted Induction Coils.—(See *Converters or Transformers.*)

Ions.—Groups of atoms or radicals which result from the electrolytic decomposition of a molecule.

The *ions* are respectively electro-positive and electro-negative. The electro-positive ion appears at the plate connected with the *electro negative terminal,* or at the *kathode,* and is called the *kathion.*

The electro-negative ion appears at the plate connected with the *electro-positive terminal.* or at the *anode,* and is called the *anion.* (See *Electrolysis. Kathion. Anion.*)

Iron-Clad Magnet.—A magnet in which the magnetic resistance is lowered by a casing of iron connected with the core and provided for the passage of the lines of magnetic force. (See *Magnet, Tubular.*)

Isobars, or Isobaric Lines.—Lines connecting places on the earth's surface which have at any time the same barometric pressure.

A study of the isobaric lines, or isobars, is of great assistance in making forecasts or predictions of coming changes in the weather.

Isochronism.—Equality of time of vibration.

Isochronous Vibrations or Oscillations.—Vibrations which perform their to and fro motions on either side of the position of rest in equal times.

The vibrations of a pendulum are isochronous, no matter what the amplitude of the swing may be, that is, whether the pendulum swings through a large arc or a small arc, provided this arc be not very great. All vibrations, therefore, that produce musical sounds may be regarded as *isochronous*.

Isoclinic Charts.—(See *Inclination Map or Charts.*)

Isoclinic Lines.—Lines connecting places that have the same angle of *magnetic dip* or *inclination.* (See *Dip, Magnetic.*)

Isodynamic Lines.—Lines connecting places which have the same *magnetic intensity.*

The magnetic intensity of a place is determined by the number of oscillations that a small magnetic needle, moved from its position of rest in the magnetic meridian of any place, makes in a given time. This method is similar to that employed for determining the intensity of gravity at any place by observing the number of oscillations that a pendulum of a given length makes in a given time at that place. If, for example, a magnetic needle at one place makes 211 oscillations in ten minutes, and 245 in the same time at another place, the relative magnetic intensities at these places are as the squares of these numbers or as 44521 : 60025, or as 1 : 1.348.

Isodynamic Map or Chart —A map of the earth on a Mercator's projection on which isodynamic lines are drawn.

An isodynamic chart is shown in Fig. 249. It will be observed that the *isodynamic lines* do not exactly coincide with the *isoclinic lines,* since the line of least magnetic intensity, does not correspond with the line of the magnetic equator.

The point of *least magnetic intensity* is found at about lat. 20° S, and long. 35° W. The point of *greatest magnetic intensity,* is found at about lat. 52° N. and long. 92° W.

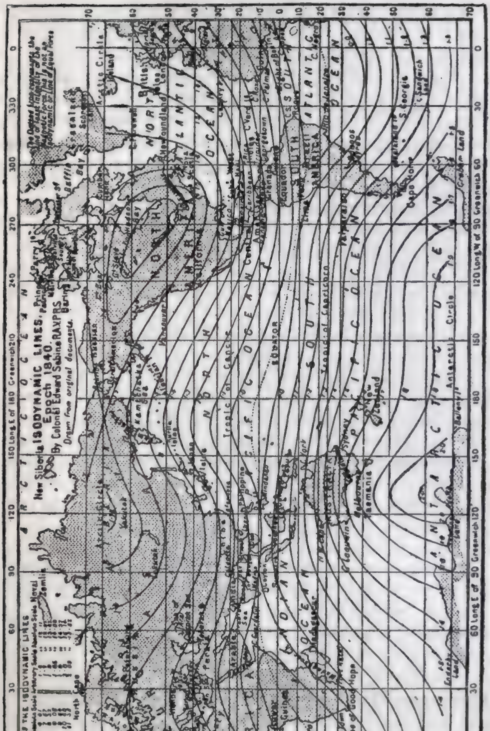


Fig. 249.

Another though weaker point of great magnetic intensity is found in Siberia. These are distinguished from the true magnetic poles by the term *Poles of Intensity.*

The *Poles of Verticity,* as determined by the *dipping needle,* and the *poles of intensity* as determined by the *needle of oscillation,* therefore do not coincide in the northern hemisphere.

Isogonal Lines.—Lines connecting places that have the same *magnetic variation* or *declination.* (See *Declination, Magnetic.*)

Isogonic or Declination Map or Chart.—A chart on which the isogonal lines are marked.

In the declination or variation chart, shown in Fig. 250, the region of western declination is indicated by the shading. There is a remarkable oval patch in the northeastern part of Asia, in which the declination is west. A similar oval of decreased declination is seen in the southern Pacific.

The entire earth acts as a huge magnet with an excess of south magnetic polarity in the northern hemisphere.

It is not known whether the earth possesses more than a single pair of magnetic poles, or what is the exact cause of its magnetism. The variations in the declination, and in the intensity of its magnetism, due to the position of the sun, as well as the marked magnetic disturbances that accompany the occurrence of sun spots, would appear to connect the earth's magnetism with the solar radiation.

It is believed by some that the earth possesses in reality the two magnetic poles, viz., a south pole in the northern hemisphere, and a north pole in the southern hemisphere. (See *False Poles, Magnetic.*)

Isotropic Conductor.—A conductor which possesses the same powers of electric conduction in all directions.

An electrically homogeneous medium.

Isotropic Medium.—A transparent medium which possesses the same optical or electric properties in all directions.

An optically homogeneous, transparent medium.

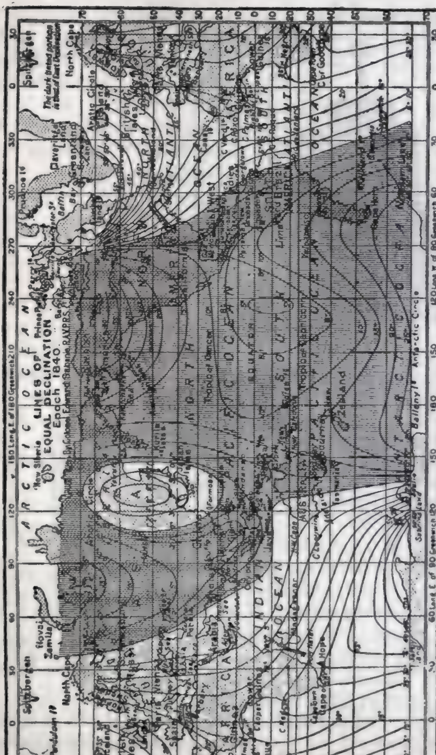


Fig. 250.

An electrically isotropic medium possesses the same powers of electric conduction or specific inductive capacity in all directions. (See *Anistropic Medium.*)

Fig. 251.

I. W. G.—A contraction for Indian Wire Gauge.

Jar, Leyden —— —A condenser in the form of a jar, in which the metallic coatings are placed opposite to each other on the outside and the inside of the jar.

The metal coatings should not extend to more than two-thirds the height of the jar, the rest of the glass being varnished to avoid the creeping of the charge over the glass in damp weather. The inside coating is connected by means of a metallic chain, to a rounded knob on the top of the jar, as shown in Fig. 251. The conductor supporting the knob passes through a dry cork or plug of some insulating material.

To charge the jar the outside coating is connected with the earth, as by holding it in the hand, and the inside coating is connected with the conductor of a machine.

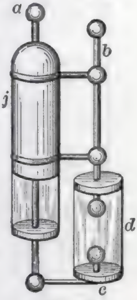


Fig. 252.

Jar, Unit —— —A small Leyden jar sometimes employed to measure approximately the quantity of electricity passed into a Leyden battery or condenser.

As shown in Fig. 252, the unit jar consists of a small Leyden jar *j*, whose outer coating is connected with a sliding metallic

rod b, provided at each end with a rounded knob, and the inner coating of which is connected with a metallic knob c, placed, and as shown, inside a glass jar d, opposite the ball on the long end of b.

When now the inside of the unit jar, or the end connected with c, is connected with the charging source, such as a machine, and the outside at a is connected with the battery that is to be charged, for every spark that passess between d and c, a definite quantity has passed at a.

The value of this *unit charge*, may be varied by varying the distance between d and c.

The smaller the unit jar in proportion to the jar to be charged, and the shorter the distance between c and d, the more reliable are the comparative results obtained.

Jet Photometer.—An apparatus for determining the candle power of a luminous source. (See *Carcel, Standard.*)

Jewelry, Electric ——.—The substitution of minute incandescent electric lamps for the rarer gems in articles of jewelry.

The lamps are lighted by means of small, primary storage batteries, carried in the pocket.

Joint Resistance of Parallel Circuits.—The joint resistance of two parallel circuits is determined by means of the following formula:

$$R = \frac{r\,r'}{r + r'} \cdot$$

Where $R =$ the joint resistance of any two circuits whose separate resistances are respectively r and r'.

When there are three resistances r, r' and r'', in parallel, the joint resistance,

$$R = \frac{r\,r'\,r''}{r\,r' + r\,r'' + r'\,r''}$$

(See *Circuits, Varieties of.*)

Joint Testing.—Ascertaining the resistance of the insulating material around the joint in a cable.

The resistance of a cable at its joint is necessarily high, since the joint forms but a small part of length of the cable. It should not, however, be large as compared with an equal length of another part of the cable with a perfect core.

Two methods for the testing of cable joints are generally employed, viz.:

(1) A condenser is charged through the joint for a given time, and the deflection obtained by its discharge is compared with the discharge of the same condenser charged for an equal length of time through a few feet of perfect cable.

(2) A charged condenser is permitted to discharge itself through the joint, and the amount lost after a given time noted.

For description of methods, see Kempe's "Handbook of Electrical Testing."

Joints, Butt —— —End to end joints.

Butt joints are formed by bringing the ends to be joined together and securing them while in such position.

Joints, Butt and Lap —— for Wires.—Joints effected in wires either by placing the wires end on, or by overlapping the ends, and subsequently soldering.

Joints, Butt and Lap —— of Belts.—The joints in a leather belt, employed for transmitting power from a line of shafting, where the ends are simply brought together and laced, is called a *butt joint*, in contradistinction to a *lap joint*, or a joint formed by placing one end of the belt over the other and lacing or riveting the two.

In delicate *galvanometers* the slightest change in the speed of the engine driving the dynamo-electric machine producing the current, causes an annoying fluctuation of the needle that prevents accurate reading, when *lap joints* are used in the belt instead of *butt joints*, unless the former are very carefully made. It also causes a flickering in the lights,

Joints, Expansion ——— —Joints for underground conductors, tubes or pipes, exposed to considerable changes of temperature, in which a sliding joint is provided to safely permit a change of length on expansion or contraction.

Joints, Lap ——— —Joints effected by overlapping short portions near the ends of the two things to be joined, and securing them while in such position.

Joints, Telegraphic, Telephonic, etc. ——— —Methods adopted for joining the ends of electric conductors so as to insure a permanent junction whose resistance shall not be appreciably greater per unit of length than that of the rest of the wire.

In making a joint care should always be taken to clean and scrape the insulating material from the wires before twisting them together.

Telegraph wires were formerly joined by the ordinary bell-hanger's joint; that is, the wires were simply looped together. The constant vibrations to which the wires are subject caused such a joint to be abandoned and an improvement introduced by bolting the ends together, as shown in Fig. 253.

This latter method is now replaced by the following, viz.:

In the *Britannia Joint*, shown in Fig. 254, the wires to be joined are placed side by side for about two inches, bound with No. 16 (British gauge) binding wire, in the manner shown, and then carefully soldered.

The *American Twist Joint*, shown in Fig. 255, is made by twisting the wires together in the manner shown and subsequently soldering.

This joint is easily made and is quite serviceable.

All joints should be soldered, but in so doing care must be taken that the soldering liquid or solid employed is free from acids or other corrosive materials, and that all traces of such materials are removed before the joint is covered with insulating material.

Kerite, Okonite, or other insulating *Tape,* should preferably be wrapped around the joint after it is soldered.

In making a joint in a gutta-percha covered wire, such as a *submarine cable wire,* or wires, the following method may be employed: The bared and cleansed wires are

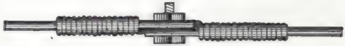


Fig. 253.

twisted together and soldered. The soldered joint is then covered with a layer of plastic insulating material made of a mixture of gutta-percha, tar and rosin. (See *Chatterton's Compound.*) In order to insure a good junction between this and the gutta-percha covering on the rest of the wire, the

Fig. 254.

outer surface of the gutta-percha is removed for about two inches from each side of the joint so as to remove its oxidized surface. After the coating is put on, it is warmed gently by a *warm joining tool* and *not by the flame of a lamp.* A sheet of warmed gutta-percha is then wrapped around the

Fig. 255.

joint, and while it and the joint are still hot, another coating of the plastic, insulating material is applied. Successive layers of gutta-percha and insulating material are generally applied in the case of submarine cables. (*Culley.*)

Joulad.—A term proposed for the *Joule,* but not generally adopted. (See *Joule.*)

Joule.—The unit of electric *energy* or *work.*

The volt-*coulomb.*

The amount of electric work required to raise the potential of one coulomb of electricity one volt

The joule may be regarded as a unit of work or energy in general, apart from electrical work or energy.

1 joule	= 10,000,000 ergs.
1 joule	= .73732 foot pound.
1 joule	= 1 volt-coulomb.
4.2 joules	= 1 small calorie.
1 joule per second	= 1 watt.

The British Association recently proposed to call one joule the work done by one watt per second.

Joule Effect.—The heating effect produced by the passage of an electric current through a conductor, arising merely from the resistance of the conductor. (See *Effect, Joule.*)

Kaolin.—A variety of white clay sometimes employed for insulating purposes.

Jablochkoff employed kaolin between the parallel carbons of his electric candle for the purpose of insulating them. He also devised an electric lamp in which a spark of considerable difference of potential, obtained from an ordinary induction coil, was caused to raise a surface of kaolin to incandescence by its passage over it.

Kathelectrotonus, or Katelectrotonus.—In electro therapeutics the condition of increased functional activity that occurs in a nerve in the neighborhood of the negative electrode, or the kathode applied in medical electricity. (See *Electrotonus.*)

Kathion.—The electro positive ion, atom, or radical into which the molecule of an electrolyte is decomposed by *electrolysis.* (See *Electrolysis. Ions.*)

Kathion is sometimes improperly written *cation.*

Kathode.—The conductor or plate of a decomposition cell connected with the negative terminal or electrode of a battery or other source.

The word kathode is sometimes applied to the negative terminal of a battery or source, whether connected with a decomposition cell or not. It is preferable, however, to restrict its use to a decomposition cell. (See *Anode.*)

The word kathode is often improperly written *cathode.*

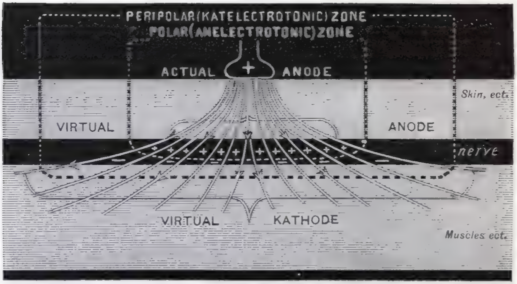


Fig. 256.

Kathodic and Anodic Electro-Diagnostic Reactions.—The reactions which occur at the kathode or anode of an electric source placed on or over any part of a living body.

Fig. 256, from DeWatteville's Medical Electricity, represents what he assumes takes place at the points of entrance and exit of the current in a nerve submitted to the action of the anode of an electric source. Two zones are formed, an anodic and kathodic; the virtual anode is formed by the portion of the skin nearer the nerve, and the virtual kathode in the adjoining muscles. There are thus formed two zones of influence,

one, immediately around the anode, called the polar, or anelectrotonic zone, and one, surrounding this and including the virtual kathode, and called the peripolar, or katelectrotonic zone.

K. C. C.—In electro therapeutics, a brief method of writing *kathodic closure contraction*, or the effects of muscular contraction observed by the closure of a circuit at the *kathode*.

K. D. C.—In electro therapeutics, a brief method of writing *kathodic duration contraction*, or the effects of muscular contraction observed at the kathode after the current has been passing for some time.

Keeper of Magnet.—A mass of soft iron applied to the poles of a magnet through which its *lines of magnetic force* pass. (See *Field, Magnetic.*)

The keeper of a magnet differs from its *armature* in that the keeper while acting as such is always kept on the poles to prevent loss of magnetization while the armature, besides acting as a keeper, may be attracted towards, or repelled from, the magnet poles. While performing its functions the keeper is always fixed; the armature generally, though not always, is in motion.

Opinion is divided, however, on the efficacy of the keeper.

Key-Board.—(See *Board, Switch.*)

Key, Discharge.—A key employed to enable the discharge from a condenser to be readily passed through a galvanometer for purposes of measurement.

Key, Discharge, Kempe's ——— —A discharge key constructed as shown in Fig. 257.

The solid lever, hinged at one extremity, plays between two contacts connected to two terminals, and has two finger triggers at its free end marked "Discharge" and "Insulate," connected to two ebonite hooks respectively. The hook attached to that marked "Discharge" is a little higher than the other, so that when the lever is caught against it, the

key rests in an intermediate position between the two contacts, and when caught against the lower trigger, it rests against the bottom contact. When in the last position, a depression of the "Insulate" trigger causes the lever to spring up against the second hook, thus insulating it from either contact, and on the depression of the "Discharge" trigger, the lever springs up against the top contact.

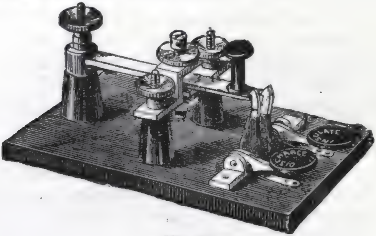


Fig. 257.

Key, Discharge, Webb's ——— —A discharge key constructed as shown in Fig. 258.

A horizontal lever L, Fig. 258, passing between two contacts and hinged at J, is pressed upwards by a spring. The free end of this lever terminates in two steps 1 and 2. A vertical lever H, provided with an insulating handle, is jointed at J′, and has, at C a projecting metallic tongue that engages in the upper step when the lever H, is vertical, and on the lower step when it is slightly moved from the free end.

When the projection C rests on the lower step 2, the lever L is intermediate between the top and bottom contacts, and is therefore disconnected from either of them ; but, when it rests on the upper step, it is in contact with the lower contact. When the lever H is so moved as to have the projection C, away from both contacts, the lever L is pressed by its spring against the upper contact.

The battery terminals are connected with the condenser terminals when the lever L, is touching the lower contact, but when the lever L, touches the top contact, the condenser is connected with the galvanometer terminals.

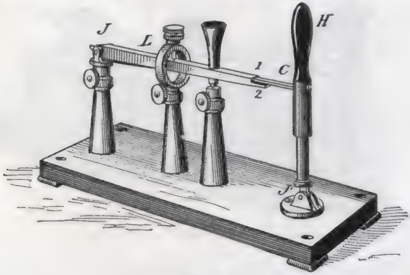


Fig. 258.

Key, Double-Contact Form of Bridge Key, Sprague's ——— —A key designed to close two separate circuits successively.

On depressing K, Fig. 259, the contacts *c*, *c*, are first closed and then those at *c'*, *c'*. Metallic pieces 1, 2, 3 and 4, serve to make contacts with apparatus used in connection therewith.

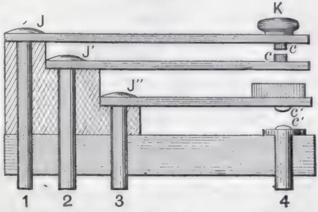


Fig. 259.

The battery circuit is connected to 1 and 2, and the galvanometer to 3 and 4, so that the battery circuit is closed first, and the galvanometer afterwards. Used in connection with the Wheatstone Bridge.

Key, Double-Contact ——, Lambert's.—A key used in cable work, and constructed as shown in Fig. 260.

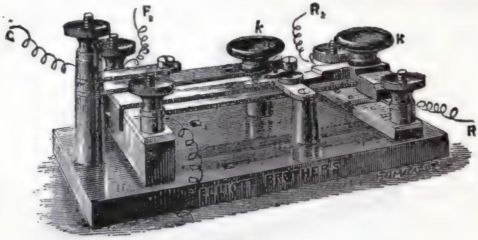


Fig. 260.

In Thomson's method for the determination of electrostatic capacity, the capacity of the cable is compared with that of a condenser containing a known charge. These two charges are so connected electrically as to discharge into and neutralize each other if equal, but if not, to produce a galvanometer deflection by a charge equal to their difference.

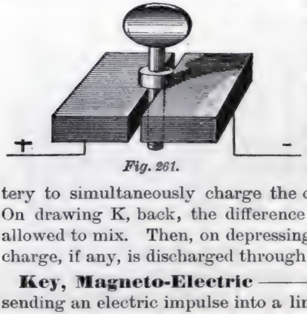


Fig. 261.

The connections are such that the pushing forward of K, depresses keys that permit a battery to simultaneously charge the condenser and the cable. On drawing K, back, the difference of the two charges are allowed to mix. Then, on depressing k, the difference of the charge, if any, is discharged through the galvanometer.

Key, Magneto-Electric ———A telegraph key for sending an electric impulse into a line, so arranged that the

coil of wire on an armature connected with the key lever, is, by the movements of the key, moved towards or from the poles of a permanent magnet, the movements of the key thus producing the currents sent into the line.

Key, Plug ——— — A simple form of key in which a connection is readily made or broken by the insertion of a plug of metal between two metallic plates that are thus introduced into a circuit.

A form of plug-key is shown in Fig. 261.

Key, Reversing ——— —A key, inserted in the circuit of a galvanometer for obtaining deflections of the needle on either side of the galvanometer scale.

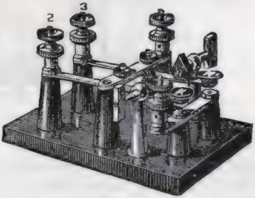


Fig. 262.

The galvanometer terminals are connected to the binding posts 2 and 3, Fig. 262, and the circuit terminals to the other two posts. On depressing K, the current flows in one direction and on depressing K′, in the opposite direction. Clamps, operated by handles, are provided so as to close either of the keys permanently, if so desired.

Key, Short-Circuit ——— —A key, which in its normal condition short-circuits the galvanometer.

Such a short-circuit key is provided for the purpose of protecting the gavanometer from injury by large currents being accidentally passed through its coils. In the form shown in Fig. 263, the spring S, rests against a platinum contact, but when depressed by the insulated head at K, it rests against an ebonite contact, and throws the galvanometer into the desired circuit.

The key is provided with double binding posts at P and N,

for convenience of attachment to resistance coils, batteries, etc.

In the form of short-circuit key shown in Fig. 264 a catch is provided for the purpose of keeping the key down when once depressed. Its arrangement will be understood from an inspection of the figure.

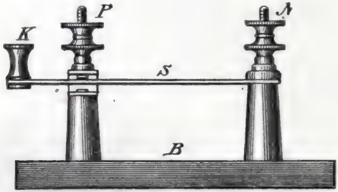


Fig. 263.

Key, Sliding-Contact ——— —The key employed in the slide form of Wheatstone's bridge, to make contact with the wire over which the sliding contact passes. (See *Balance, Wheatstone's, Slide Form of.*)

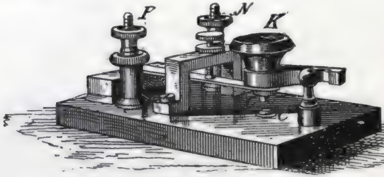


Fig. 264.

Key, Telegraphic ——— —The key employed for sending over the line the successive makes and breaks that produce the dots and dashes of the Morse alphabet, or the deflections of the needle of the needle telegraph. (See *Telegraphy, American or Morse System of.*)

Kilo (as a prefix).—One thousand times.

Kilodyne.—One thousand dynes. (See *Dyne.*)

Kilogramme.—One thousand grammes, or 2.2046 lbs. avoirdupois. (See *Weights, French System of.*)

Kilojoule.—One thousand joules.

Kilometre.—One thousand metres.

Kilowatt.—One thousand watts.

Kine.—A unit of velocity proposed by the British Association.

A kine equals one centimetre per second.

Kinetic Energy.—Energy which is actually doing work, as distinguished from energy that only possesses the power of doing work, or *potential energy.* (See *Energy.*)

Kite, Franklin's ——— —A kite raised in Philadelphia, Pa., in June, 1752, by means of which Franklin experimentally demonstrated the identity between lightning and electricity, and which, therefore, led to the invention of the lightning rod.

It is true that Dalibard, on the 10th of May, 1752, prior to Franklin's experiment, succeeded in drawing sparks from a tall iron pole he had erected in France. This experiment was, however, tried at the suggestion of Franklin, and must properly be ascribed to him.

The following description of this kite is given by Franklin in the following letter:

Letter XI., from BENJ. FRANKLIN, Esq., of Philadelphia, to PETER COLLINSON, Esq., F.R.S., London.

"OCT. 19, 1752.

"As frequent mention is made in public papers, from Europe, of the success of the Philadelphia experiment for drawing the electric fire from clouds by means of pointed rods of iron erected on high buildings, etc., it may be agreeable to the

curious to oe informed that the same experiment has succeeded in Philadelphia, though made in a different and more easy manner, which is as follows:

"Make a small cross, of two light strips of cedar, the arms so long, as to reach to the four corners of a large thin handkerchief, when extended; tie the corners of the handkerchief to the extremities of the cross, so you have the body of a kite; which, being properly accommodated with a tail, loop, and string, will rise in the air, like those made of paper; but this, being of silk, is fitter to bear the wet and wind of a thunder gust without tearing. To the top of the upright stick of the cross is to be fixed a very sharp pointed wire, rising a foot or more above the wood. To the end of the twine, next the hand, is to be tied a silk ribbon, and where the silk and twine join, a key may be fastened. This kite is to be raised when a thunder gust appears to be coming on, and the person who holds the string must stand within a door or window, or under some cover, so that the silk ribbon may not be wet; and care must be taken that the twine does not touch the frame of the door or window. As soon as any of the thunder clouds come over the kite, the pointed wire will draw the electric fire from them, and the kite, with all the twine will be electrified, and the loose filaments of the twine will stand out every way, and be attracted by an approaching finger. And when the rain has wet the kite and twine, so that it can conduct the electric fire freely, you will find it stream out plentifully from the key on the approach of your knuckle. At this key the phial may be charged; and from electric fire, thus obtained, spirits may be kindled, and all the other electric experiments be performed, which are usually done by the help of a rubbed glass globe or tube, and thereby the sameness of the electric matter with that of lightning completely demonstrated. B. FRANKLIN."

Kyanizing.—A process employed for the preservation of wooden telegraph poles by injecting a solution of corrosive

sublimate into the pores of the wood. (See *Poles, Telegraphic.*)

Lag, Magnetic ——— —The tendency of the iron core of a magnet, or of the armature of a dynamo-electric machine, to resist and therefore retard magnetization.

This retardation, or lag, is called the *magnetic lag.*

The *lead* necessary to give the brushes of a dynamo-electric machine to ensure quiet action has by some been erroneously ascribed to the magnetic lag. The lead, though due to lag in part, is, in reality, mainly due to the resultant magnetization of the armature by both the field magnets and by its own current. (See *Angle of Lead.*)

This displacement is measured by an angle sometimes called the *angle of lag.* (See *Angle of Lag.*)

Lamination of Core.—The subdivision of the core of the armature of a dynamo-electric machine into separate insulated plates or strips for the purpose of avoiding *eddy currents.*

This lamination must always be perpendicular to the direction of the eddy currents that would otherwise be produced. (See *Eddy Currents*).

Lamellar Distribution of Magnetism, Magnetic Shell.—The distribution of magnetism in magnetic shells.

A *magnetic shell* is a thin sheet or disc of magnetized material whose opposite extended faces are of opposite magnetic polarities, and the extent of whose surface is very great as compared with its thickness.

The field produced by a magnetic shell is exactly similar to that produced by a closed voltaic circuit, the edges of the space inclosed by which correspond to the edges of the magnetic shell.

Magnetic Density or *Intensity*, or the number of lines of force per unit area of cross section, is equal over all parts of the surface of a simple magnetic shell. The strength of such

a shell will therefore be equal to its thickness multiplied by its surface density.

A magnetic shell may be conceived as consisting of a very great number of exceedingly short, straight, magnetic needles placed side by side, with their north poles terminating at one of the faces of the sheet and their south poles at the opposite face, the breadth of the sheet being very great as compared with its thickness. Such a distribution of magnetism is known as a *lamellar distribution.*

Fig. 265.

Lamp, Arc, Electric —— —An electric lamp in which the light is produced by a voltaic arc formed between two or more carbon electrodes.

The carbon electrodes are placed in various positions, either parallel, horizontal, inclined, or vertically one above the other. The latter is the form most generally adopted, since it permits the ready feeding of the upper carbon.

The carbons are maintained during their consumption, at a constant distance apart, by the aid of various *feeding devices.* Such devices consist generally of trains of wheelwork, mechanical or electric motors, or are operated by the simple action of a spring, gravity or a solenoid.

The carbon pencils or electrodes are held in *carbon holders*, consisting of *clutches* or *clamps*, attached to the ends of the *lamp rods.*

When the lamp is not in operation the carbons are usually in contact with one another ; but, on the passage of the current, they are separated the required distance by the action of an electromagnet whose coils are traversed by the direct current.

In order to maintain the electrodes a constant distance apart, the upper carbon is held in position by the operation of a clutch in some lamps, or, in others, by a detent, that engages in a toothed wheel. The position of this clutch or detent is controlled by the action of an electro-magnet whose coils are usually situated in a *shunt* or *derived circuit*, of high resistance, around the electrodes. When the carbons are at their normal distance apart, the shunt current is not of sufficient strength to move the clutch or detent from the position in which it prevents the downward motion of the upper carbon rod. When, however, by the burning or consumption of the carbons, the resistance of the arc has increased to an extent which can be predetermined, the increased current that is thereby passed through the shunt circuit is now sufficiently strong to release the clutch or detent, thus permitting the fall or feed of the upper carbon. In a well designed lamp this occurs so gradually as to produce no perceptible effect on the steadiness of the light.

Arc lamps are generally placed in *series circuits*, that is, the current passes successively through all the lamps in the circuit, and returns to the source. In order to avoid the breaking of the entire circuit, an *automatic safety device* is provided: This consists essentially of an electro-magnet placed in a shunt circuit, so that, when the resistance of the arc becomes very great, the increased current, flowing through the coils of the electro-magnet, produces a movement of its armature which closes a short circuit around the lamp, and thus cuts it out of the circuit. (See *Device, Safety.*)

Arc lamps assume a great variety of forms. A well known form is shown in Fig. 265.

Lamp Bracket, Electric ——— —(See *Bracket, Lamp.*)

Lamp, Carcel ——— —(See *Carcel Lamp.*)

Lamp, Differential Arc ——— —An arc lamp in which the movements of the carbons are controlled by the differen-

tial action of two magnets opposed to each other, one of whose coils is in the direct, and the other in a shunt circuit around the carbons.

Sometimes the differential coils are placed on the same magnet core.

Lamp-Hours.—The number of lamp-hours is obtained by multiplying the number of lamps by the average number of hours during which they are burning.

A method of estimating the current supplied to a consumer by counting the number of hours each lamp is in service.

To convert *lamp-hours* to *watt-hours* multiply the number of lamp-hours by the number of watts per lamp. The *watt-hours*, divided by 746, will then give the *electrical horse-power hours*. (See *Watt-Hours.*)

Lamp, Incandescent Electric—— —An electric lamp in which the light is produced by the electric incandescence of a strip or filament of some refractory substance, generally carbon.

The carbon strip or filament is usually bent into the form of a horseshoe or arc, and placed inside a glass vessel, called the *lamp chamber*. This vessel is exhausted by means of a mercury pump, generally to a fairly high vacuum.

In order to insure the complete removal from the lamp chamber of all the air it originally contained, both it and the carbon strip that is placed within it are maintained at a high temperature during the process of exhaustion. This temperature in practice is obtained by sending the current through the carbon strip as soon as the air is nearly all removed. Towards the end of the pumping operation the current is increased so as to raise the carbons to their full brilliancy.

This latter operation is termed the *occluded-gas process*, and is essential to the successful sealing of an incandescent lamp. By its means, a considerable quantity of air or other gaseous substances shut up or occluded by the carbon, is

driven out of the carbon, which it would be impossible to get rid of by the mere operation of pumping. In order to insure the success of the operation *it is necessary* that *the heating must take place while the lamp is being exhausted,* since otherwise the expelled gases would be reabsorbed. (See *Gases, Occlusion of.*)

The exhaustion continues up to the moment the lamp chamber is hermetically sealed.

The lamp chamber is usually hermetically sealed by the fusion of the glass in the manner adopted in the sealing of Geissler tubes, or Crooke's radiometers.

Fig. 266.

For the preparation of the carbon strip, its carbonization, and the flashing of the strip see *Carbonization, Processes of,* and *Flashing of Carbons, Process for.*

The ends of the carbon strip, or arc, are attached to *leading-in wires* of platinum that pass through the glass walls of the lamp chamber, and are fused therein by melting the glass around them, in the same manner as are the leading-in wires in Geissler tubes and other similar apparatus.

Incandescent lamps are generally connected to the leads or circuits, in *multiple-arc,* or in *multiple-series circuits;* they are, however, sometimes connected to the line in *series.* (See *Circuits, Varieties of.*)

In the former case their resistance is comparatively high; in the latter case, comparatively low.

Incandescent electric lamps assume a variety of different forms. One of them is shown in Fig. 266. The lamp chamber conforms in general shape to the outline of the filament.

Lamp, Semi-Incandescent Electric ——— —An electric lamp, in which the light is due to the combined effects

of a voltaic arc, and electric incandescence. In the Reynier semi-incandescent lamp, shown in Fig. 267, a thin pencil of carbon C, is gently pressed against a block of graphite B. A lateral contact is provided at L, through a block of graphite I, by means of which the current is conveyed to the lower part only of the movable rod C, which part alone is rendered incandescent.

In this lamp the light is due to both the incandescence of the rod C, and to the small arc formed at J, between its lower end and the contact block B, though mainly from the latter.

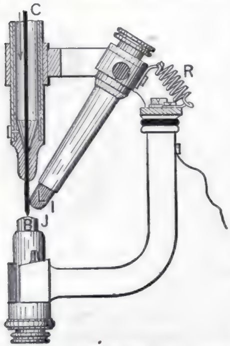


Fig. 267.

Latent Electricity.—A term formerly applied to bound electricity. Now in disuse. (See *Bound*, *Dissimulated* or *Disguised Electricity.*)

Lateral Discharge.—A small discharge observed on the discharge of a Leyden jar, between parts of the jar not in the circuit of the main discharge.

If a charged Leyden jar is placed on an insulating stool, and is then discharged by the discharging rod, the lateral discharge is seen as a small spark that passes between the outside coating of the jar and a body connected with the earth at the moment of the discharge through the rod. This lateral discharge is due to a small excess of free electricity on the outside, that is not neutralized by the opposite charge.

A *lateral discharge* is also seen in the sparks that can be taken from a conductor in good connection with the earth, by holding the hand near the conductor, while it is receiving

large sparks from a powerful machine in operation. These discharges are due to induction.

Lateral Induction.—Induction observed between closely approached portions of a circuit, through which the disruptive discharge of a Leyden jar is passed as a long spark, thereby making the resistance of the circuit high.

A long copper wire, bent in the form of an open rectangle, has its free ends bent near their extremities so as to approach each other until but half an inch apart. The extreme end of one of the extremities is provided with a metallic ball, and the other end connected with the earth. If, now, a Leyden jar charge is passed through the wire, by connecting the outer coating with the end of the earth connected wire, and holding the inside coating near the knob, a spark will pass through the half inch of air space between the approached portions of the circuit.

This discharge is due to what was called formerly *lateral induction.* The discharge from the approached parts of the wire is probably to be regarded as a branch discharge, or shunt current, due to the fact that the accumulated resistance of the wire to the current of the disruptive discharge, becomes greater than that of the air space between the approached parts of the wire.

Law, Natural ——— —A correct expression of the order in which the causes and effects of natural phenomena follow one another.

The law of gravitation, for example, correctly expresses the order of sequence of the phenomena which result when unsupported bodies fall to the earth. It should be carefully borne in mind, however, that natural laws cannot be regarded as explaining the *ultimate causes of natural phenomena,* but merely express their order of occurrence or sequence.

We are, ignorant, for example, of the true cause of gravitation and are only acquainted with its effects. This is true of

all ultimate physical causes, save for the belief in their origin in a Divine will.

Laws, Ampère's——or Laws of Electro-Dynamic Attraction and Repulsion.—Laws expressing the attractions and repulsions of electric circuits on one another.

Laws, Becquerel's——or Laws of Magneto-Optic Rotation.—Laws of the magneto-optic rotation of the plane of polarization of light. (See *Magneto-Optic Rotation.*)

Laws of Coulomb, or Laws of Electrostatic and Magnetic Attractions and Repulsions.—Laws for the force of attraction and repulsion between charged bodies or between magnet poles.

The fact that the force of electrostatic attraction or repulsion between two charges, is directly proportional to the product of the quantities of electricity of the two charges and inversely proportional to the square of the distance between them, is known as *Coulomb's Law.* Coulomb also ascertained that the attractions and repulsions between magnet poles is directly proportional to the product of the strength of the two poles, and inversely proportional to the square of the distance between them. This is also called Coulomb's Law.

Laws of Faraday, or Laws of Electrolysis.—Laws for the effects of electrolytic decomposition. (See *Electrolysis.*)

Laws of Kirchoff, or Laws of Shunt-Circuits.—The laws of *branched* or *shunted circuits.*

These laws may be expressed as follows :

(1) In any number of conductors meeting at a point, if currents flowing to the point be considered as $+$, and those flowing away from it as $-$, the algebraic sum of the meeting currents will be zero.

This is the same thing as saying as much electricity must flow away from the point as flows toward it.

(2) In any system of closed circuits the algebraic sum of the products of the currents into the resistances is equal to the electro-motive force in the circuit.

In this case all currents flowing in a certain direction are taken as positive, and those flowing in the opposite direction as negative. All electro-motive forces tending to produce currents in the direction of the positive current are taken as positive, and those tending to produce currents in the opposite direction, as negative.

This follows from Ohm's law; for, since $C = \frac{E}{R}$, the electro-motive force $E = CR$, and this is true no matter now often the circuit is branched.

Laws of Lenz.—Laws for determining the directions of the currents produced by electro magnetic or electro dynamic induction. (See *Lenz's Law.*)

Law of Ohm, or Law for Current Strength.—A fundamental law for determining the current strength in any circuit.

The strength of the current in any circuit is directly proportional to the electro-motive force, and inversely proportional to the resistance of the circuit.

$C = \frac{E}{R}$, or $E = C\ R$. (See *Ohm's Law.*)

Law of Volta, or Law for Contact-Series.—A law for the differences of electric potential produced by the contact of dissimilar metals or other substances.

"*The difference of potential between any two metals is equal to the sum of the differences of potential between the intervening substances in the contact-series.*" (See *Contact Electricity. Contact-Series.*)

Layer, Crookes' ——— —A layer, or stratum, in the residual atmosphere of a vacuous space, in which the molecules recoiling from a heated or electrified surface do not

meet other molecules, but impinge on the walls of the vessel directly opposite to such heated surface.

A Crookes' layer may result as the effect of two different causes, viz.:

(1) The rarefaction of the gas is such that the distance between the walls of the vessel and the heated surface is less than the mean free path of the molecules.

(2) The wall is so near the heated surface that the distance between the two is less than the actual mean free path of the molecules. Under these last named circumstances, Crookes' layers may result whatever be the density of the gas.

Lead of Brushes of Dynamo-Electric Machine. (See *Angle of Lead.*)

Leading Horns of Dynamo-Electric Machine. (See *Horns, Leading, of Dynamo Electric Machine.*)

Leads.—The main conductors of any system of electric distribution.

The leads, or main conductors in a multiple system of incandescent lighting, must maintain a constant potential at the lamp terminals. The dimensions of the leads are therefore so proportioned as to absorb as small an amount of potential as possible. Since in incandescent lighting, where the lamp is connected to the leads in multiple-arc, the total resistance of the lamps is comparatively small, the resistance of the leads must necessarily be quite small in order to avoid a marked drop of potential. Comparatively large conductors must therefore be used.

The main conductor for series circuits, such as for arc lights, has in all parts the same current strength. Since the resistance of the lamp in such a circuit is quite high, a comparatively high resistance in the conductor can be employed without a proportionally large absorption of potential. Comparatively small conductors can therefore be used. (See *Systems of Current Distribution by Constant and by Alternating Currents.*)

Leakage, Electric ——— —The gradual dissipation of a charge or current due to insufficient insulation.

Some leakage occurs under nearly all circumstances. On telegraph lines, during wet weather the leakage is often so great as to interfere with the proper working of the lines.

The leakage of a well insulated conductor, placed in a high vacuum, is almost inappreciable. Crookes has maintained electric charges in his high vacua for years without appreciable loss.

Leakage Conductor.—A conductor placed on a telegraph circuit, to prevent the disturbing effects of *leakage* into a neighboring line by providing a direct path for such leakage to the earth.

The leakage conductor, as devised by Varley, consists of a thick wire attached to the pole. The lower end of the conductor is well grounded, and its upper end projects above the top of the pole.

There exists some doubt in the minds of experienced telegraph engineers whether it is well to apply leakage conductors to telegraphic or telephonic lines of over 12 or 15 miles in length, since such conductors greatly increase the electrostatic capacity of the line, and thus cause serious retardation.

Leakage, Magnetic ——— —A useless dissipation of the lines of magnetic force of a dynamo-electric machine, or other similar device, by their failure to pass through the armature. (See *Magnetophone.*)

Leclanché's Voltaic Cell. (See *Cell, Voltaic.*)

Legal Ohm.—The resistance of a column of mercury one square millimetre in cross-section and 106 centimetres in length, at the temperature of 0° C. or 32° F. (See *B. A. Unit.*)

1 Ohm = 1.00112 B. A. Unit. This value of the ohm was adopted by the International Electric Congress, in 1884, as a value that should be accepted internationally as the true value of the ohm.

Length of Spark.—The length of spark that passes between two charged conductors depends:

(1) On the difference of potential between them.

(2) On the character of the gaseous medium that separates the two conductors.

(3) On the density or pressure of the gaseous medium between the conductors. Up to a certain pressure, a decrease in the density causes an increase in the length of the distance the spark will pass. When this limit is reached, a further decrease of density decreases the length of spark. A high vacuum prevents the passage of a spark even under great differences of potential.

(4) On the kind of material that forms the electrodes between which the charges pass.

(5) On the shape of the charged conductor.

(6) On the direction of the current. Sparks from the prime conductor are denser and more powerful than those from the negative conductor.

It will be observed that the length of the spark practically depends mainly on two circumstances, viz., on the differences of potential of the opposite charges, and the conducting power of the medium that separates the two bodies.

Lenz' Law.—The direction of the currents set up by electro-magnetic induction is always such as to tend to oppose the motion producing them.

Letter-Boxes, Electric ———.—Various devices that announce the deposit of a letter in a box, by the ringing of a bell or the movement of a needle or index.

These devices generally act by the making or opening of an electric circuit by the fall of the letter in the box.

Leyden Jar. (See *Jar, Leyden.*)

Leyden-Jar Battery. (See *Battery, Leyden Jar.*)

Lichtenberg's Figures. (See *Figures, Lichtenberg.*)

Life of Electric Incandescent Lamps.—The number of hours that an incandescent electric lamp, when traversed by the normal current, will continue to afford a good commercial light.

The failure of an electric incandescent lamp results either from the volatilization or rupture of the carbon conductor, or from the failure of the vacuum of the lamp chamber. Since the employment of the flashing process, and the process for removing the occluded gases it is not unusual for incandescent lamps to have *a life of several thousand hours.* (See *Flashing Carbons, Process for.*)

Light, Electro-Magnetic Hypothesis of ——— —A hypothesis for the cause of light proposed by Maxwell, based on the relations existing between the phenomena of light and those of electro-magnetism.

Maxwell's electro-magnetic theory of light assumes that the phenomena of light and magnetism are each due to certain motions of the ether. Electricity and magnetism being due to its rotations or oscillations, and light to its to-and-fro motions.

He proposed this theory to show that the phenomena of light, heat, electricity and magnetism could all be explained by one and the same cause, viz., a vibratory or oscillatory motion of the particles of the hypothetical ether. Maxwell died before completing his hypothesis, and it has never since been sufficiently developed to thoroughly entitle it to the name of a theory.

There are, however, numerous considerations which render it probable that electric and magnetic phenomena, like those of light and heat, have their origin in a vibratory or oscillatory motion of the luminiferous ether. A few of these, as pointed out by Maxwell, S. P. Thompson, Lodge, Larden and others, are as follows:

(1) It is quite possible that the thing called electricity is the ether itself; negative electrification consisting in an *excess* of

the ether, and positive electrification in a *deficit*. (See *Hypotheses of Electricity.*)

(2) It is possible that electrostatic phenomena consist in a *strain* or *deformation* of the ether. A *dielectric* may differ from a conductor in that the former may have such an attraction for the ether as to give it the properties of an elastic solid, while in the latter the ether is so free to move that no strain can possibly be retained by it. (See *Dielectric. Conductor.*)

(3) Dielectrics are transparent and conductors are opaque.

There are exceptions to this in the case of vulcanite and many other excellent dielectrics. Nor should this similarity be expected to be general in view of the difference between diathermancy and transparency.

(4) It is possible that an electric current consists of a real motion of translation of the ether through a conductor.

(5) It is possible that electro-motive force results as differences of *ether pressures*, this would of course follow from (4).

(6) The vibrations of light are propagated in a direction at right angles to the direction in which the light is moving. The magnetic field of a current is propagated in planes at right angles to the direction in which the current is flowing.

(7) It is possible that lines of electrostatic and magnetic force consist of chains of polarized ether particles.

(8) The velocity of propagation of light agrees very nearly with the velocity of propagation of electro-magnetic induction. (See *Velocity Ratio.*)

(9) In certain axial crystals the difference of transparency in the direction of certain axes, corresponds with the direction in which such crystals conduct electricity.

Light-House Illumination, Electric ——— ——— ——— —The application of the electric arc light to the illumination of light houses.

A powerful arc light is placed in the focus of the dioptric lens now commonly employed in light houses. Since the con-

sumption of the carbon electrodes would alter the position of the focus of the light, electric lamps for such purposes are constructed to feed *both* of their carbons instead of the upper carbon only, as in the case of the ordinary arc lamp.

Light, Intensity of—— —(See *Intensity of Light. Photometer.*)

Lighting, Central Station —— —The lighting of a number of houses or other buildings from a single station, centrally located.

Central station lighting is distinguished from *isolated lighting*, by the fact that a number of separate buildings, houses, or areas are lighted by the current produced at a single station, centrally located, instead of from a number of separate electric sources located in each of the houses, etc., to be lighted. (See *Systems of Electric Distribution.*)

Lightning.—The spark or bolt that results from the *discharge* of a cloud to the earth, or to a neighboring cloud. (See *Atmospheric Electricity. Kite, Franklin's.*)

Lightning Arrester.—A device, by means of which the apparatus placed in any electric circuit are protected from the destructive effects of a flash or bolt of lightning.

In the phenomena of *lateral induction* we have seen the tendency of a *disruptive* discharge to take a short cut across an intervening air space, rather than through a longer though better conducting path. Most lightning arresters are dependent for their operation on this tendency to lateral discharge. (See *Induction, Lateral. Discharge, Disruptive.*)

A form of lightning arrester is shown in Fig. 268.

The line wires A and B, are connected by two metallic plates to C and D, respectively.

These plates are provided with points, as shown, and placed near a third plate, connected to the ground by the wire G. Should a bolt strike the line, it is discharged to the earth through the wire G.

Lightning, Back or Return Stroke.—(See *Back or Return Stroke of Lightning.*)

Lightning, Globular ——— —A rare form of lightning, in which a globe of fire appears for a while, quietly floats in the air, and then explodes with great violence.

The exact cause of globular lightning is unknown. Phenomena allied to it, however, have been observed by Planté during the discharge of his rheostatic machine, when discharged in *series*, or for a great difference of electric *potential.* Similar phenomena, are sometimes, though rarely, observed during the discharge of a powerful Leyden battery. Sir Wm. Thomson ascribes the effect to an optical illusion.

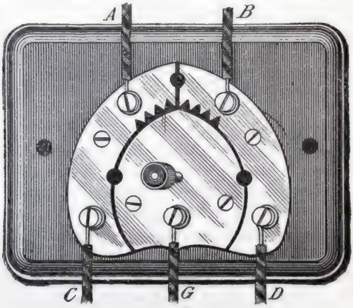


Fig. 268.

Lightning, Heat or Sheet, Volcanic and Zigzag ——— —*Heat* or *sheet lightning* is the name given to a discharge unaccompanied by any thunder audible to the observer, in which the entire surfaces of the clouds are illumined.

Its cause has been ascribed to the reflection from the clouds of lightning flashes too far below the horizon to permit them to be directly seen, or the thunder to be audible,

If a Geissler tube, which contains several concentric tubes, be charged by a Holtz machine, and then touched at different parts by the hands, a succession of luminous discharges will be seen in the dark, that bear a remarkable resemblance to the flashes of *heat* or *sheet lightning.*

Lightning Rods.—A rod, or wire cable of good conducting material, placed on the outside of a house or other structure, in order to protect it from the effects of a lightning discharge.

Lightning rods were invented by Franklin. The result of a very extended inquiry recently made on the subject, leaves no room for doubt that a lightning rod, properly constructed and placed, affords an efficient protection to the buildings on which it is placed.

To insure this protection, however, all the following conditions must be carefully fulfilled, else the rod may prove a source of danger rather than a protection, viz.:

(1) The rod, generally of iron or copper, should have such an area of cross section as to enable it to carry without fusion the heaviest bolt it is liable to receive in the latitude in which it is located. When of iron, the area of cross section should be about seven times greater than when of copper.

(2) The rod should be continuous throughout, all joints being carefully avoided. If these be used they should be made of as low resistance as possible and should be protected against corrosion.

(3) The upper extremity of the rod should terminate in one or more points formed of some metal that is not readily corroded, such as platinum or nickel.

(4) The lower end of the rod should be carried down into the earth until it meets permanently damp or moist ground, where it should be attached to a fairly extended metallic surface buried in the ground. Metallic plates will answer for the purpose, but, if gas or water pipes are available, the rod should

be placed in good electrical connection therewith, by wrapping *it around* and *soldering* it to such pipes.

This fourth requirement is of great importance to the proper action of a lightning rod, and unless thoroughly fulfilled may render the rod worthless, no matter how carefully the other requirements are attended to. When a bolt strikes a lightning rod which is not properly grounded, the discharge is almost certain to destroy the building to which the rod is connected.

(5) The rod should not be insulated from the building, unless to prevent stains from the oxidation of the metal. On the contrary it should be directly connected with all masses of metal in its path, such as tin roofs, gutter-spouts, metallic cornices, etc. In this way only can dangerous disruptive lateral discharges from the rod to such masses of metal be avoided.

(6) The rod should project above the roof or highest part of the building, or, in other words, the height of the rod should bear a certain proportion to the size of the building to be protected. A rod will protect a conical space around it, the radius of whose base is equal to the vertical height of the rod above the ground, but whose sides are curved inwards instead of being straight. Where the building is very high, a number of separate rods *all connected to one another* should be employed.

(7) A stranded conductor is much better than an equal cross section of a solid rod of the same metal.

A lightning rod more frequently acts to quietly discharge an impending cloud by *convective discharge*, than by an actual *disruptive discharge* of the same. (See *Discharge, Convective. Discharge, Disruptive.*)

Lightning rods should be frequently tested to see that no breaks or oxidation of their joints have occurred.

Lightning Rods for Ships.—A system of rods designed to afford electric protection for vessels at sea.

Since the lightning discharge takes place between the points of greatest difference of potential, and these are gener-

ally between the cloud and the nearest point of the earth, tall objects are especially liable to be struck.

Ships at sea should, therefore, be thoroughly protected from lightning.

In Harris' system of lightning protection for ships, the rods are connected with a series of copper plates and rods so placed on the masts as to readily yield to strains. These are electrically connected with the copper sheathing of the vessel and *with all large masses of metal* in the vessel. This latter precaution is especially necessary in the case of men-of-war, in order to protect the powder magazine. Harris' method for the lightning protection of ships, which was adopted only after very considerable opposition, proved so efficacious in practice that serious effects of lightning on vessels so protected are now almost unknown. In 1845, Harris received the honor of knighthood from the English Government for his services in this respect.

A lightning rod sometimes fails to protect a house or barn from the fact that a heated, ascending current of air from a fire in the house, or from the gradual heating of green hay or grain in the barn, increases the virtual height of the house beyond the ability of its rod to protect it.

Lightning, Volcanic ——— —The lightning discharges that attend most volcanic eruptions.

Volcanic lightning is probably due to the friction of volcanic dust particles against one another, or against the air, but particularly to the sudden condensation of the vapor that is generally disengaged during volcanic eruptions.

Lightning, Zigzag, Chain or Forked ——— —The commonest variety of lightning flashes in which the discharge apparently assumes a forked zigzag, or even a chain-shaped path.

This form is seen in the discharge of a Holtz machine, or of a *Ruhmkorff Induction Coil.*

The irregular shape of the path is probably due to the resistance of solid particles in the air, which are piled up in front of the discharge, or to the effects of the *lateral induction* that is produced during the discharge. (See *Induction, Lateral.*)

Line, Neutral —— of a Magnet.—A line joining the neutral points of a magnet, or the points approximately midway between the poles.

This is sometimes called the *equator of the magnet.*

The neutral point is the point where the lines of force outside the magnet are parallel to the surface of the magnet. (*Hering.*)

Line, Neutral —— of Commutator Cylinder.—A line on the commutator cylinder of a dynamo-electric machine, connecting the neutral points, or the points of maximum positive and negative difference of potential. (See *Dynamo-Electric Machine.*)

Line, Telegraphic, Telephonic, etc. —— —The conducting circuit provided for the transmission of the electric impulses or currents employed in any system of electric transmission.

Lines, Aclinic, or Isoclinic —— —Lines connecting places that have the same *magnetic inclination.* (See *Aclinic Line. Isoclinic Line.*)

Lines, Agonic, or Isogonic —— —Lines connecting places that have an equal *magnetic declination.* (See *Agone.*)

Lines, Isodynamic—— —(See *Isodynamic Lines.*)

Lines of Electrostatic Force.—Lines extending in the direction in which the force of electrostatic attraction or repulsion acts.

Lines of electrostatic force pass through dielectrics; whether the force acts by means of a polarization of the dielectric, or by means of a tension set up in it, is not known. (See *Field, Electrotastic.*)

Lines of Force, Direction of —— —— —— —Lines extending in the direction in which the lines of magnetic force are assumed to pass.

The lines of magnetic force are assumed to come *out of* the *north pole of a magnet*, and to pass *in* at its *south pole.*

The lines of electrostatic force are assumed to pass *out of a positively charged* surface, and *into a negatively charged* surface.

Lines of Magnetic Force.—Lines extending in the direction in which the force of magnetic attraction or repulsion acts. (See *Field, Magnetic.*)

Liquids, Specific Resistance of ——— — The resistance of a given length (one centimetre) and cross section (one square centimetre) of any liquid as compared with the resistance of an equal length and cross section of pure silver.

The resistance of a few common liquids and solutions is here given from Lupton:

Water, pure at 75° C	1.188×10^8	ohms
i. e., 118,800,000.		
Water at 4° C	9.100×10^6	"
Water at 11° C	3.400×10^5	"
Dilute hydrogen sulphate (sulphuric acid) at 18° C. 5 per cent. acid	4.88	
Dilute hydrogen sulphate at 18° C. 3 per cent. acid	1.38	"
Nitric acid, at 18° C. density 1.32	1.61	"
Saturated solution of copper sulphate (blue vitriol) at 10° C	29.30	"
Saturated solution of zinc sulphate at 14° C.	21.50	"
Hydrochloric acid, 20 per cent. acid, at 18° C.	1.34	"
Sal ammoniac, 25 per cent. salt	2.53	"
Common salt, saturated, at 13° C.	5.30	"

It will be observed that the resistance varies considerably with differences of temperature.

Local Action.—*In a battery,* the loss of energy by the irregular and wasteful solution of the *zinc* or *positive* element by the electrolyte.

The local action of a battery is caused by the solution of the zinc or positive plate by the action of local voltaic couples formed by couples of zinc and minute particles of carbon, lead, or other impurities. It is remedied by the *amalgamation* of the zinc. (See *Zinc, Amalgamation of.*)

In a dynamo electric machine, the loss of energy by the setting up of *eddy currents* in the conducting masses of the pole-pieces, cores, etc. (See *Currents, Eddy.*)

In a dynamo electric machine local action is obviated by a *lamination of the pole pieces, armature core, etc.* (See *Lamination of Cores.*)

Local Battery.—(See *Battery, Local.*)

Local Currents.—(See *Currents, Eddy.*)

Localization of Faults.—Determining the position of a fault in a telegraph line or cable by calculations based on the fall in the potential of the line measured at different points or by loss of charge, etc.

For description see standard works.

Locomotive, Electric —— —A railway engine whose motive power is electricity. (See *Railroad Electric.*)

Locomotive Head-Light, Electric —— —(See *Head-Light, Electric.*)

Lodestone.—A name applied by the ancients to an ore of iron (magnetic iron ore), that naturally possesses the power of attracting light pieces of iron to it.

Lodestone, or magnetic iron ore, must be regarded as a magetizable substance that has become permanently magnetic from its situation in the earth's magnetic field. Such beds of ore concentrate the lines of the earth's magnetic field on them, and thus become magnetic.

Log, Electric ——— —An electric device for measuring the speed of a vessel.

Any log that operates by the rotation of a wheel is caused to register the number of rotations by a step-by-step recording apparatus operated by breaks in the circuit, made during the rotation of the wheels, at any given number of turns, say 100, or any other convenient multiple. Such a log may be kept constantly in the water, and observed when required, or it can be made to register a permanent record of its actual speed at any time during the entire run.

Logarithms.—The logarithm of any given number, is the exponent of the power to which it is necessary to raise a fixed number, in order to produce the given number.

A table of logarithms enables the operations of multiplication, division, and the extraction of roots, to be readily performed by simple multiplication, division, addition or subtraction. When thoroughly understood, logarithms greatly reduce the labor of mathematical calculations. For the manner in which they are used the student is referred to any standand work on mathematics.

Longitude, Electrical Determination of ——— —The determination of the longitude of a place, by differences in time between it and a place on the prime meridian, as simultaneously determined telegraphically.

In determinations of this character allowance must be made for the retarding effects of long telegraphic lines, or cables.

Loop, Electric ——— —A portion of a main circuit consisting of a wire going out from one side of a break in the main circuit and returning to the other side in the break.

Loops are employed for the purpose of connecting a branch telegraph office with the main line; for placing one or more electric arc lamps on the main line circuit; for connecting a *messenger call*, or *telephone circuit* with a main line; and for numerous similar purposes.

Loxodrograpn.—An apparatus for electrically recording on paper the actual course of a ship by the combined action of magnetism and photography.

Luces.—Plural of *lux*. (See *Lux.*)

Lux.—A name proposed by Preece for the unit of intensity of illumination.

One lux is the illumination given by a standard candle at the distance of 12.7 inches.

One lux is the illumination given by a carcel at the distance of one metre.

One lux is the illumination given by a lamp of 1,000 candles at 105.8 feet. (See *Illumination, Unit of.*)

Machine, Frictional Electric —————— ——————— —

A machine for the development of electricity by friction.

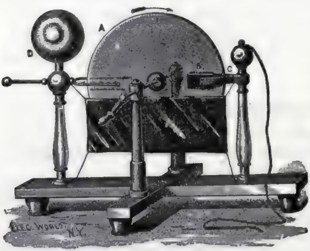


Fig. 271.

A frictional electric machine consists of a plate or cylinder of glass A, Fig. 271, capable of rotation on a horizontal axis.

A rubber formed of a chamois skin, covered with an amalgam of tin and mercury, is placed at B. By the rotation of the plate the rubber becomes negatively, and the glass positively excited. An insulated conductor D, called the *prime* or *positive conductor*, provided with a comb of points, becomes positively charged by induction. The machine will develop electricity best if a conductor attached to the

rubber is connected with the ground, as by a chain, as shown.

Machines, Electrostatic Induction —— —— or Influence Machines.—Machines in which a small initial charge produces a greatly increased charge by its inductive action on a rapidly rotated disc of glass.

An excellent type and example of such a machine is found in the Holtz machine which consists of the following parts, as shown in Fig. 272, viz. :

(1) A stationary glass plate A, fixed at its edges to insulated supports.

(2) A movable plate B, capable of rapid rotation on a horizontal axis, by a driving pulley.

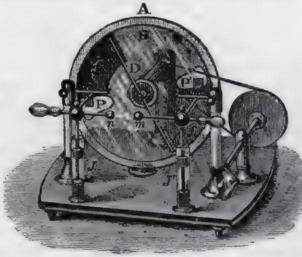


Fig. 272.

(3) Armatures of varnished paper *f*, *f'*, placed on opposite sides of the fixed plate at holes or windows P, P', cut in the plate. The armatures are placed on the side of the fixed plate away from the moving plate, or on the back of the plate, so that the plate, on its rotation, moves *towards tongues of paper* attached to the middle of the *armature*.

(4) Metal combs placed in front of the movable disc opposite the armatures, and connected with the brass balls *m*, *n*, one of which is movable towards and from the other by means of a suitably supported insulating handle connected with it.

A small initial charge is given to one of the armatures by holding a plate of electrified vulcanite on it, and rotating the machine *while the balls m, n, are in contact.* As soon as the machine is charged the balls are *gradually separated,* when a torrent of sparks will pass between them so long as the plate is rotated.

When the balls are separated too far the sparks cease to pass. The balls must then be again brought into contact and gradually separated as before.

The Holtz machine can be regarded as a revolving *electrophorus* provided with means for constantly discharging and recharging the upper metallic plate. (See *Electrophorus*).

The action of the machine is well described by S. P. Thompson in his "Elementary Lessons on Electricity and Magnetism," as follows:

"Suppose a small + charge to be imparted at the outset to the right armature *f*; this charge acts inductively across the discs upon the metallic comb, repels electricity through it, and leaves the points negatively electrified. They discharge negatively electrified air upon the front surface of the movable disc; the repelled charge passes through the brass rods and balls, and is discharged through the left comb upon the front side of the movable disc. Here it acts inductively upon the paper armature, causing that part of it which is opposite itself to be negatively charged and repelling a + charge into its farthest part, viz., into the tongue, which being bluntly pointed, slowly discharges a + charge upon the *back* of the movable disc. If now the disc be turned round, this + charge on the back comes over from the left to the right side, in the direction indicated by the arrow, and, when it gets opposite the comb, increases the inductive effect of the already existing + charge on the armature, and therefore repels more electricity through the brass rods and knobs into the left comb. Meantime the — charge, which we saw had been induced in the left

armature, has in turn acted on the left comb, causing a + charge to be discharged by the points upon the front of the disc; and, drawing electricity through the brass rods and knobs, has made the right comb still more highly —, increasing the discharge of — ly electrified air upon the front of the disc, neutralizing the + charge which is being conveyed over from the left. These actions result in causing the top half of the moving disc to be — ly electrified. The charges on the front serve as they are carried round, to neutralize the electricities let off by the points of the combs, while the charges on the back, induced respectively in the neighborhood of each of the armatures, serve, when the rotation of the disc conveys them round, to increase the inductive influence of the charge on the other armature."

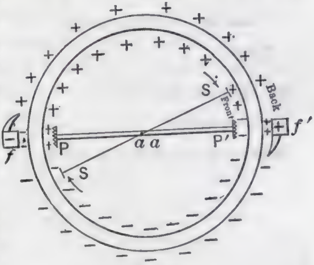


Fig. 273.

The student will be aided in following Prof. T.'s explanation by the diagrammatic sketch, shown in Fig. 273. Here the rotating plate is shown for convenience in the form of a cylinder. The armatures are shown on the back of the plate at *f′* and *f*, opposite the brass collecting combs P′ and P, with their discharging rods and balls *a a*.

The effect of the positive charge given to the right hand armature *f′*, directly through the combs P′, rods *a a*, comb P, to left hand armature *f*, is readily seen. The rotation of the plate being in the direction of the curved arrows, the charging of the front of the plate by convection streams from the combs, and the back of the plate from the points

of the paper armatures, as well as the character of the charge will be understood. There thus results, as is shown, a positive charge on both the front and back of the upper half of the rotating plate, and a negative charge on both sides of its lower half. A reversal of polarity of the plate occurs at the line P *a a* P′. Sometimes the reversal does not occur and the machine either loses its charge entirely, or in part. A conductor S S, furnished with points, is sometimes provided to lessen the chances of lack of reversal.

Machines, Faradic ——— —(See *Faradic Machines.*)

Made Circuit.—(See *Circuit, Closed.*)

Magne-Crystallic Action.—A term proposed by Faraday to express the differences in the action of magnetism on crystalline bodies in different directions.

A needle of tourmaline if hung with its axis horizontal is no longer paramagnetic as usual, but diamagnetic. The same is true of a crystal of bismuth. Faraday concluded from these experiments that a force existed distinct from the paramagnetic or diamagnetic force. He called this the *magne-crystallic force.*

Plücker infers from these phenomena that a definite relation exists between the *ultimate form of the particles of matter and their magnetic behavior.* The subject may be regarded as yet somewhat obscure. (See *Diamagnetic Polarity.*)

Magnet.—A body possessing the power of attracting the unlike poles of another magnet or repelling the like poles; or of attracting readily magnetizable bodies like iron filings to either pole.

A body possessing a magnetic field.—(See *Field, Magnetic.*)

The lines of force are assumed to pass through the magnetic field out at the north pole and in at the south pole. All lines of force form closed magnetic circuits. If a magnetizable body is brought into a magnetic field, the lines of magnetic force

are concentrated on it and pass through it. The body therefore becomes magnetic. The intensity of the resulting magnetism depends on the number of lines of force that pass through the body, and the polarity on the direction in which they pass through it.

Magnet, Anomalous ———— —A magnet which possesses more than two poles.—(See *Anomalous Magnet.*)

Magnet, Artificial ———— —A magnet produced by induction from another magnet, or from an electric current.

Any magnet not found in nature is called an *artificial magnet.*

Magnet, Bell Shaped ———— —A modification of a horseshoe shaped magnet in which the approached poles are semi-annular in shape, and form a split tube.

Bell magnets are used in many galvanometers, because they can be readily dampened by surrounding them by a mass of copper. The needle in its motion produces currents that tend to oppose and therefore to stop its motion. (See *Lenz's Law.*)

Magnet Coils.—The coils of insulated wire surrounding the core of an electro magnet, and through which the magnetizing current is passed.—(See *Magnetism, Ampère's Theory of. Dynamo Electric Machine, Field Magnets.*)

Magnet, Compensating ———— —A magnet placed over a magnetic needle, generally over the magnetic needle of a galvanometer, for the purpose of varying the direction and intensity of the magnetic force of the earth on the needle.—(See *Galvanometer, Reflecting.*)

A magnet, called a *compensating magnet*, is sometimes placed on a ship, near the compass needle, for the purpose of neutralizing the local variation produced on the compass needle by the magnetism of the ship.

Magnet, Compound ——— —A number of single magnets, placed parallel and with their similar poles facing one another, as shown in Fig. 274.

Compound magnets are stronger in proportion to their weight than single magnets.

Magnet, Electro ——— —A magnet produced by the passage of an electric current around a core of soft iron.—(See *Electro-Magnet.*)

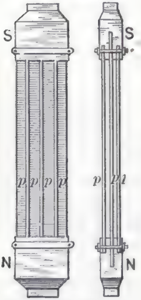


Fig. 274.

Magnet, Horseshoe ——— —(See *Horseshoe Magnet.*)

Magnet, Keeper of ——— —(See *Keeper of Magnet.*)

Magnet, Permanent ——— —A magnet of hardened steel or other substance which retains its magnetism for a long time after being magnetized.

A permanent magnet is distinguished, in this respect, from a temporary magnet of soft iron which loses its magnetization very shortly after being taken from the magnetizing field.

Magnet, Portative Power of ——— —The lifting power of a magnet.

The *portative*, or *lifting power of a magnet,* depends on the form of the magnet, as well as on its strength. A horseshoe magnet, for example, will lift a much greater weight than the same magnet if in the form of a straight bar.

This is due not only to the mutual action of the approached poles, but also to the decreased resistance of the magnetic circuit, and to the greater number of lines of magnetic force that pass through the armature.

The portative power increases as the area of contact increases.

Magnet, Receiving ——— **or Relay.**—(See *Relay.*)

Magnet, Simple ————A single magnetized bar.

Magnet, Solenoidal ——— —A long, thin, uniformly magnetized straight bar of steel, with its poles at its extremities, that acts on external objects as if equal and opposite quantities of magnetism were collected at its extremities.

It derives its name *solenoidal*, from the similarity between its action and that of a *solenoid*. Unless very carefully magnetized a magnet will not act as a solenoidal magnet. (See *Electro-Magnet. Solenoidal Distribution of Magnetism.*)

Magnet, Tubular ——— or Iron-Clad Magnet.—A form of horseshoe magnet in which one pole is brought near the opposite pole by a hollow cylinder or tube, which is placed in contact with one of the magnetic poles, so as to completely surround the other, except in the plane of cross section of that pole.

There is thus obtained a magnet, with two concentric poles, one solid and one annular, the portative power of which is much greater than that of a horseshoe magnet of equal dimensions.

Magnetic Attraction.—(See *Attraction, Magnetic.*)

Magnetic Axis.—(See *Axis, Magnetic.*)

Magnetic Azimuth.—(See *Azimuth, Magnetic.*)

Magnetic Battery.—(See *Battery, Magnetic.*)

Magnetic Bridge.—(See *Bridge, Magnetic.*)

Magnetic Circuit.—(See *Circuit, Magnetic.*)

Magnetic Couple.—(See *Couple, Magnetic.*)

Magnetic Curves.—Curved lines, formed by sprinkling iron filings on a sheet of paper or glass held in the field of a magnet, and gently tapping the same so as to permit the filings to arrange themselves in the direction of the lines of magnetic force. (See *Figures, Magnetic.*)

Magnetic Declination.—The angular deviation of the magnetic needle to the east or west of the true geographical north. (See *Needle, Declination of. Declination Chart.*)

Magnetic Density.—(See *Density, Magnetic.*)

Magnetic Dip.—(See *Dip, Magnetic.*)

Magnetic Explorer.—(See *Explorer, Magnetic.*)

Magnetic Field.—The atmosphere of magnetic influence which surrounds the poles of a magnet.

Any space traversed by lines of magnetic force, forms a magnetic field. (See *Field, Magnetic.*)

Magnetic Figures.—(See *Figures Magnetic. Field, Magnetic.*)

Magnetic Filament.—A polarized line or chain of ultimate magnetic particles. (See *Filament, Magnetic.*)

Magnetic Force.—The force which causes magnetic attractions and repulsions.

Magnetic Inclination.—The angular deviation from a horizontal position of a freely suspended magnetic needle. (See *Dip of Needle. Inclination Chart.*)

Magnetic Induction.—The magnetization of magnetizable substances by bringing them into a magnetic field. (See *Induction, Magnetic.*)

Magnetic Inertia.—(See *Inertia, Magnetic. Lag, Magnetic.*)

Magnetic Intensity.—(See *Intensity of Magnetization.*)

Magnetic Lag.—(See *Lag, Magnetic.*)

Magnetic Leakage.—Useless dissipation of lines of magnetic force outside that portion of the field of a dynamo electric machine through which the armature moves.

Magnetic leakage will result in a low efficiency of the dynamo. (See *Coefficient, Economic of Dynamo.*)

Magnetic Lines of Force.—(See *Lines of Force, Magnetic.*)

Magnetic Masses.—(See *Masses, Magnetic.*)

Magnetic Memory.—A term proposed by J. A. Fleming for *coercive force.*

Soft iron has but a feeble memory of its past magnetization.

Magnetic Meridian.—The magnetic meridian of any place is the meridian which passes through the poles of a magnetic needle, when in a position of rest under the free influence of the earth's magnetism at that place.

The *plane of the magnetic meridian* of a place is a vertical plane passing through the poles of a magnetic needle in a position of rest under the free influence of the earth's magnetism at that place.

Magnetic Moment.—The magnetic moment of a magnetic needle is *the product of one of the two forces of the directive couple, multiplied by the perpendicular distance between the directions of these forces ;* or, in other words, the moment of a magnet is equal to its length multiplied by the intensity of the magnetism of one of its poles. (See *Couple, Magnetic*).

Magnetic Observatory.—(See *Observatory, Magnetic.*)

Magnetic Permeabitity.—Conductibility for lines of magnetic force.

Iron is a substance which possesses great magnetic permeability. When placed in a magnetic field the lines of force are concentrated on and readily pass through its mass, or, in other words, its *magnetic resistance* is low. All *paramagnetic bodies,* have a high *magnetic permeability.* (See *Paramagnetic*)

Magnetic Poles, False —— —(See *False Poles, Magnetic.*)

Magnetic Reluctance.—A term recently proposed in place of magnetic resistance, to express the resistance offered

by a medium to the passage through its mass of the lines of magnetic force.

Magnetism, Residual ——— —The small amount of magnetism retained by soft iron when removed from a magnetizing field.

Magnetic Resistance.—Resistance offered by a medium to the passage of the lines of magnetic force through it.

The magnetic resistance of the circuit of the lines of force is reduced by forming the circuit of a medium having a *high magnetic permeability*, such as soft iron. This is accomplished by the *armature* or *keeper* of a magnet, or by the iron in an *ironclad magnet*. (See *Iron-Clad Magnet.*)

Magnetic Retentivity.—(See *Retentivity, Magnetic.*)

Magnetic Saturation.—The condition of iron, or other paramagnetic substance, when its intensity of magnetization is so great that it fails to be further magnetized by any magnetic force however great.

When the core of an electro-magnet is saturated by the passage of an electric current, the only further increase of its magnetization that is possible, is that due to the magnetic field of the increased current which may be sent through its coils. This is comparatively insignificant.

A magnet is sometimes said to be *super-saturated*, that is, to have received more magnetism than it can retain for any considerable time after its magnetization.

Magnetic Screen, or Shield.—A hollow box whose sides are made of thick iron, placed around a magnet or other body so as to cut it off or screen it from any magnetic field external to the box.

Magnetic screens are placed around delicate galvanometers to avoid any variations in their field due to extraneous masses of iron, or neighboring magnets. They are also sometimes placed around watches to shield or screen the works from the effects of magnetism.

To act effectively, when the external fields are at all powerful, magnetic screens must be made of thick iron. They differ in this respect from *electrostatic shields*, which will afford protection against electrostatic charges although they may be but mere films. (See *Shields, Electrostatic.*)

Magnetic Shells.—A sheet or layer consisting of magnetic particles, all of whose north poles are situated in one of the flat surfaces of the sheet, and the south poles in the opposite surface. (See *Shell, Magnetic. Lamellar Distribution of Magnetism.*)

Magnetic Solenoids.—A spiral coil of wire which acts like a magnet when an electric current passes through it. (See *Solenoids, Electro-Magnetic.*)

Magnetic Sounds.—Faint clicks heard on the magnetization of a readily magnetizable substance.

One of the earlier forms of Reis' telephone operated by means of a rapid succession of these faint, magnetic sounds.

Magnetic Storms.—Sudden, but small and irregular variations in the intensity of the earth's magnetism that simultaneously affect all parts of the earth.

Magnetic storms have been observed to accompany auroral displays, and to be coincident with the occurrence of *sun spots*, or unusual outbursts of solar activity.

Magnetic Susceptibility.—The relation which exists between the strength of the magnetizing field and that of the magnetized body, or the intensity of the magnetism induced, divided by the intensity of the inducing field.

When the inducing field has unit strength of magnetization the magnetic susceptibility will measure directly the strength of the magnetization.

When a bar of iron is placed in a magnetic field, it is threaded by the lines of magnetic force, and thus becomes magnetized by *induction*. This induction will necessarily

depend both on the number of lines of force in the magnetizing field, and on the *magnetic permeability* of the magnetized body; or, in other words, the *induction* is equal to the product of the intensity of the magnetizing field and the magnetic permeability of the body in which the induction occurs.

Magnetic Variations.—Variations in the value of the *magnetic declination*, or *inclination*, that occur simultaneously over all parts of the earth.

These variations are:

(1) Secular, or those occurring at great cycles of time.

(2) Annual, or those occurring at different seasons of the year.

(3) Diurnal, or those occurring at different hours of the day, and,

(4) Irregular, or those accompanying magnetic storms. The first three are periodical; the last is irregular. (See *Angle of Declination. Variation Chart. Inclination Chart.*)

Magnetite.—Magnetic oxide of iron, or $Fe_3 O_4$.

Lodestone consists of pieces of magnetized magnetite.

Magneto-Electricity.—Electricity produced by the motion of magnets past conductors, or of conductors past magnets.

Magneto-Electric Call Bell.—An electric call bell operated by currents produced by the motion of a coil of wire before the poles of a permanent magnet.

Magneto-Electric Induction.—Electric induction produced by the motion of a conductor past a permanent magnet, or *vice versa*. (See *Induction, Electro Magnetic.*)

Magneto-Electric Machine.—A dynamo in which currents are produced by the motion of armature coils past permanent magnets. (See *Dynamo Electric Machine.*)

Magnetograph, or Self-Recording Magnetometer.—A self-recording apparatus by means of which the daily

and hourly variations of the magnetic needle are continuously registered.

The magnetograph, as employed in the observatory at Kew, consists essentially of a photographic record of a spot of light reflected from a mirror attached to the needle whose variations are to be recorded. The photographic record is received on a strip of sensitized paper, maintained in uniform and continuous motion by means of suitable clockwork. The record so obtained is called a *magnetograph.*

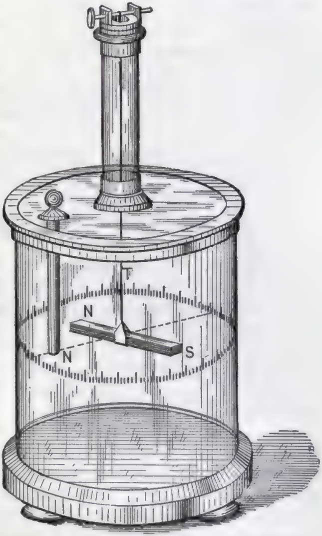


Fig. 275.

Magnetometer. — An apparatus for the measurement of magnetic force by the torsion balance.

The principles of the operation of the magnetometer are the same as those of the *torsion balance.* (See *Balance, Coulomb's Torsion.*) A magnet N S, Fig. 275, is suspended by a single wire, and the magnet N, whose strength is to be measured is introduced in an opening at the top of the glass cage, in place of the proof plane which is used when the apparatus is employed for measuring the force of electrostatic attraction and repulsion.

In delicate magnetometers, the construction of which differs considerably from the form shown in Fig. 275, the deflection of the magnet is measured by a beam of light reflected from a mirror attached to the axis of suspension.

Magneto-Optic Rotation.—The rotation of the plane of polarization of a beam of light on its passage through a transparent medium placed in a strong magnetic field, which medium only possesses such properties while in the field.

In a ray of ordinary light the vibrations of the ether particles are at right angles to the direction of the ray, or to the direction in which the light is moving. Successive ether particles that lie along the path of the ray, do not, however, perform their vibrations in the same plane. Each successive particle moves in a plane which, though at right angles to the ray, is slightly inclined to the neighboring particle.

The motion of the particles therefore, would describe a screw-like path through space. Under certain circumstances, all the ether particles may be caused to move in planes that are parallel to one another. Such a beam of light is called a *plane polarized beam.*

A plane polarized beam, when passed through many transparent substances, will have its ether particles vibrating in the same plane when it emerges from the medium, as it had before it entered. Other substances possess the property of *rotating* or *turning* the *plane of polarization of the light* to the right or to the left. This property is called respectively *right-handed rotary polarization,* and *left-handed rotary polarization.*

Many substances that ordinarily possess no power of rotary polarization acquire this power when placed in a magnetic field. This property of a magnetic field was discovered by Faraday. The effect is to be ascribed to the strain produced in the transparent medium by the stress of the magnetic field. It may be caused in solid bodies by mechanical force.

The apparatus for demonstrating the rotation of the plane of polarization by a magnetic field is shown in Fig. 276.

A powerful electro-magnet M, N, is provided with a hollow core. The substance *c*, is placed in the field thus produced by the approached poles, and its action on the light of a lamp, placed opposite at *l*, is observed by suitable apparatus at *a*.

Magnetophone.—An apparatus for measuring the number of breaks or interruptions of a circuit by the pitch of the musical note heard in an *electro-magnetic telephone* placed in such circuit. (See *Telephone, Electro-Magnetic.*)

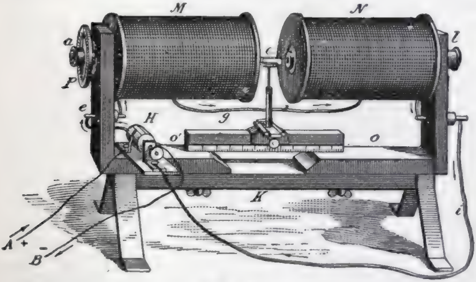


Fig. 276.

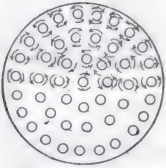
A similar apparatus is useful in studying the distribution of the magnetic field of a dynamo electric machine. In this case, a small thin coil of insulated wire is held in the different regions around the machine, while the telephone is held to the ear of the observer. Magnetic leakage, or useless dissipation of lines of magnetic force outside the field proper of the machine, is at once rendered manifest by the musical note caused by variations in the intensity of the field.

Since the intensity of the note heard will vary according to

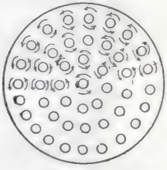
the intensity of the field, and also according to the position in which the coil is held, such a coil becomes a *magnetic explorer*, and by its use the distribution and varying intensity of an irregular field can be ascertained. Its use is especially advantageous in proportioning dynamo-electric machines, and electric motors.

Magnetism.—That branch of science which treats of the properties of a *magnetic field*. (See *Field, Magnetic.*)

Magnetism, Ampère's Theory of.—A theory or hypothesis proposed to account for the cause of magnetism by the presence of electric currents in the ultimate particles of matter.



Unmagnetized
Fig. 277.



Magnetized
Fig. 278.

This theory assumes .

(1) That the ultimate particles of all magnetizable bodies have closed electric circuits in which electric currents are continually flowing.

(2) That in an unmagnetized body these circuits neutralize one another because they have different directions.

(3) That the act of magnetization consists in such a polarization of the particles as will cause these currents to flow in one and the same direction, *magnetic saturation* being reached when all the separate currents are parallel to one another.

(4) That the *coercive force* is due to the resistance these circuits offer to a change in the direction of their planes.

Figs. 277 and 278, show the circular paths of some of these circuits. Fig. 277 shows the assumed condition of an unmagnetized bar. Fig. 278 the assumed condition of a magnetized bar.

A careful inspection of the figures will show that in a magnetized bar all the separate currents flow in the same direction. *All the circuits except those on the extreme edge of the bar will, therefore, have the currents flowing in them in opposite directions to that in their neighboring circuits, and, therefore, will neutralize one another. There will remain, however, a current in a circuit on the outside of the bar, which must therefore be regarded as the magnetizing circuit.*

Guided by these considerations, Ampère produced a coil of wire, called a *solenoid*, which is the equivalent of the magnetizing circuit assumed by his theory.

It therefore follows that an electric current sent through a coil of insulated wire surrounding a rod or bar of soft iron, or other readily magnetizable material, will make the same a magnet. A magnet so produced is called an electro-magnet. (See *Electro-Magnet.*)

The magnetizing coil is called a helix or solenoid. (See *Solenoid, Electro-Magnetic.*)

The polarity of the magnet depends on the direction of the current, or on the direction of winding of the helix or solenoid. (See *Solenoids, Sinistrorsal and Dextrorsal.*)

Magnetism, Electro ——————Magnetism produced be means of electric currents.

The discovery of Oersted, in 1820, of the action of an electric current on a magnetic needle, was almost immediately followed by the simultaneous and independent discoveries of Arago and Davy, of the method of magnetizing iron by the passage of an electric current around it.

These observations were first reduced to a *theory* by Ampère. (See *Magnetism, Ampère's Theory of. Electro-Magnet.*)

Magnetism, Hughes' Theory of————A theory propounded by Hughes to account for the phenomena of magnetism apart from the presence of electric currents.

Hughes' theory, or, more strictly speaking, hypothesis of magnetism, though very similar to that of Ampère, does not assume the improbable condition of a constantly flowing electric current.

Hughes' hypothesis assumes:

(1) That the molecules of matter, and probably even the atoms, possess naturally opposite magnetic polarities which are respectively + and —, or N. and S.

Fig. 279.

(2) That these molecules, when arranged in closed chains or circuits, are capable of neutralizing one another so far as external action is concerned.

Two such arrangements or groupings are shown in Figs. 279 and 280. It will be observed that the magnetic chain or circuit is complete, and that, therefore, the substance can possess no magnetic properties so far as external action is concerned.

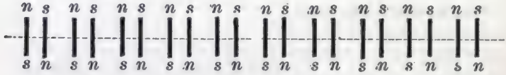


Fig. 280.

(3) That the act of magnetization consists in such a rotation of the molecules, that a *polarization* of the substance is effected; that is, the molecules are rotated on their axes so that one set of poles tend to point in one direction, and the other set of poles in the opposite direction.

Partial magnetization consists in partial polarization. Magnetic saturation is reached when the polarization is complete. (See *Magnetic Saturation.*)

Coercive force is the resistance the body offers to the polarization or rotation of its molecules. (See *Coercive Force.*)

Hughes' hypothesis of magnetism would appear to be strengthened by the following facts :

(1) A bar of steel or iron is sensibly elongated on being magnetized. This would naturally result if the molecules be supposed to be longer in one direction than in any other.

(2) A tube, furnished at its ends with plates of flat glass and filled with water containing finely divided magnetic oxide of iron, is nearly opaque to light when unmagnetized, but will permit some light to pass through it when magnetized.

(3) A magnet, if cut at its neutral point, will possess opposite polarities at the cut ends ; and no matter to what extent this subdivision is carried the particles will still possess opposite polarities.

These facts are, however, also explained by Ampère's hypothesis of magnetism, with, however, the improbable assumption of a constantly flowing current in each molecule.

Magnetism, Lamellar—— —(See *Lamellar Magnetism.*)

Magnetism, Solenoidal Distribution of—— —A term sometimes applied to a distribution of magnetism in a bar such that the magnetized particles are arranged with their poles in the direction of the length of the bar, in contra-distinction to a lamellar distribution. (See *Lamellar Distribution of Magnetism.*)

Magnetization, Coefficient of—— —(See *Coefficient of Magnetization.*)

Magnetization, Critical Current of—— —(See *Critical Current of Magnetization.*)

Magnetization, Methods of ———— —Magnetization effected either by induction from another magnet, or by means of induction by an electric current.

The substance to be magnetized is brought into a magnetic field, so that the lines of magnetic force pass through it. All methods of magnetization may be divided into methods of *touch*, and *magnetization by the electric current.*

Mains, Electric ——— —The principal conductors in any system of electric distribution. (See *Leads, Electric.*)

Mallet, Electro-Magnetic ——— — (See *Electro-Magnetic Mallet.*)

Manipulator, Breguet's ——— —(See *Needle Telegraph.*)

Manometer.—An apparatus for measuring the tension or pressure of gases.

Manometers are either mercurial or metallic. They measure the pressure of gases either in *atmospheres, i. e.*, in multiples or decimals of 15 pounds to the square inch, or in inches of mercury.

Marine Galvanometer.—(See *Galvanometer, Marine.*)

Mariners' Compass.—(See *Compass, Azimuth.*)

Marked Pole of a Magnet.—The pole of a magnet that points approximately to the geographical north.

If the pole of the magnet that points to the geographical north be in reality the north pole of the magnet, then the earth's magnetic pole in the Northern Hemisphere is of south magnetic polarity. In the United States, and Europe generally, this is regarded to be the fact.

The French, however, call the pole of the needle that points to the earth's geographical north, the *south* or *austral* pole. In America and England it is called *the north pole*, the *marked pole*, or *the north-seeking pole*, and the Northern Hemisphere is assumed to possess south magnetic polarity. (See *Austral* and *Boreal Poles.*)

Markers.—Green flags, or signal lights, displayed on the ends of trains, in systems of block railway signalling in order to avoid accidents from trains breaking in two. (See *Block Signals, System of.*)

Mass.—The quantity of matter contained in a body.

Mass must be carefully distinguished from *weight.* The weight of a given quantity of matter depends on the attraction which the earth possesses for it, and this, on the earth's surface, varies with the latitude, being greatest at the poles, and least at the equator. It also varies with different elevations above the level of the sea. The *mass,* however, is the same under all circumstances.

Mass, Magnetic ——— —Such a quantity of magnetism, that at unit distance produces an action equal to unit force.

Mass, Unit of ——— —The quantity of matter which under certain conditions will balance the weight of a standard *gramme* or *pound.*

Masses, Electric ——— —A mathematical conception for such quantities of electricity that at unit distance will produce an attraction or repulsion equal to unit force.

Electrical masses are assumed to be equal when they produce on two identical bodies of small dimensions charges of the same electric force.

Master-Clock.—The central or controlling clock in a system of electric time distribution, from which the time is transmitted to the *secondary clocks* in the circuit. (See *Clocks, Electric.*)

Matter.—That which occupies space and prevents other matter from simultaneously occupying the same space.

Matter is composed of *atoms,* which unite to form *molecules.* (See *Atoms. Molecules.*)

Matter, Elementary ——— —(See *Element.*)

Matter, Radiant, or Ultra-Gaseous ——— —A term proposed by Crookes for the peculiar condition of the matter which constitutes the residual atmospheres of high vacua.

The peculiar properties of radiant matter are seen in the mechanical effects of the localized pressure produced when such residual atmospheres are locally heated or electrified.

In *Crookes' Radiometer*, vanes of mica, silvered on one face and covered with lampblack on the opposite face, are supported on a vertical axis, so as to be capable of rotation and placed in a glass vessel in which a *high vacuum* is maintained. On exposing the instrument to the radiation from a candle or gas flame, a rapid rotation takes place.

The explanation is as follows: The lampblack covered surfaces absorb the radiant heat, and becoming heated the molecules of gas in the residual atmosphere are shot violently from these heated surfaces, and by their reaction drive the vanes around in the opposite direction to that from which they are thrown off. The molecules are also shot off from the silvered surfaces, but, as these are cooler, the effect is not as great as at the blackened surfaces.

In a gas, at ordinary pressure, the heated surfaces are also bombarded by other molecules of the gas, but in high vacua the mean free path of the molecules is such that there is no interference, a *Crookes' layer* existing between the vanes and the walls of the glass vessel. (See *Layer, Crookes'*.)

When a Crookes' tube is furnished with suitable electrodes, and electric discharges are sent through it between these electrodes, a stream of molecules is thrown off in straight lines from the *surface of the negative electrode.*

Some of the effects of this *molecular bombardment* are seen by the use of the apparatus shown in Fig. 281. When the positive and negative terminals are arranged as shown, the paths of the molecular streams are seen as luminous streams whose directions are those shown in the figures.

The figure on the left shows the path taken in a *low vacuum*. Streams pass from the negative electrode to *each of the positive electrodes*.

The figure on the right shows the discharge in a *high vacuum*. Here the streams pass off at right angles to the face

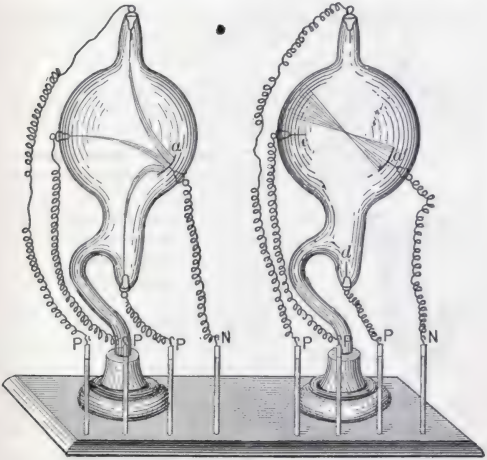


Fig. 281.

of the negative electrode, and proceed therefrom in straight lines, independently of the position of the positive electrode. Since, therefore, the negative electrode at a, is in the shape of a concave mirror, the luminous particles converge to a focus near the centre of the glass vessel, and then diverge to the opposite wall.

Refractory substances placed at such a *focus of molecular bombardment*, as shown in Fig. 282, are rendered incandescent.

In a similar manner, phosphorescent substances exposed to such molecular streams emit a beautiful phosphorescent light. (See *Phosphorescence, Electric.*)

Measurements, Electric ——— —Determinations of the values of the E. M. F., resistance, current, capacity, energy, etc., in any electric circuit.

Electric measurements may be either qualitative or quantitative.

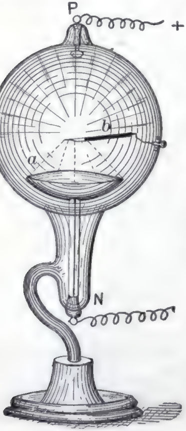


Fig. 282.

Mechanical Equivalent of Heat.—The amount of mechanical energy converted into heat that would be required to raise the temperature of one pound of water 1° F.

The mechanical equivalence between the energy expended and the heat produced.

Joule's experiments, the results of which are generally accepted, gave 772 foot pounds as the energy equivalent to that expended in raising the temperature of one pound of water 1° F.

Media, Anisotropic ——— —(See *Anisotropic Media.*)

Meg or Mega (as a prefix.)—One million times; as *megohm*, one million ohms; *mega-volt*, one million volts.

Meidinger's Voltaic Cell.—(See *Cell, Voltaic.*)

Meridian, Geographic ——— —The geoprahic meridian of a place is a great circle passing through the place and the north and south geographic poles of the earth.

Meridian, Magnetic ——— —The great circle passing through the poles of a magnetic needle at rest in the earth's magnetic field.

Metallic Arc.—A voltaic arc formed between metallic electrodes. (See *Arc, Voltaic.*)

Metallic Circuit.—Any circuit that is mainly metallic throughout, or of which the ground or earth does not form a part. (See *Circuit, Metallic.*)

Metallochromes or Nobili's Rings.—Prismatic colored deposits obtained by the electrolytic decomposition of metallic salts under certain conditions.

These deposits consists of peroxide of lead which appears at the positive electrode. The colors, like those produced by soap-bubble films, or by the iridescence of mother-of-pearl, or by films of oil floating on the surface of water, etc., are due to the interference of the light reflected from the upper and lower surfaces of films which are deposited in different thicknesses.

Metalloid.—A name formerly applied to a non-metallic body, or to a body having only some of the properties of a metal as carbon, boron, oxygen, etc.

The term is now but little used.

Metals, Deflagration of ——— —The volatilization of metals, generally by electric incandescence.

Metals, Electrical Protection of ——— —The protection of a metal from corrosion by placing it in connection with another metal, which, when exposed to the corroding liquid, vapor, or gas will form with the metal to be protected, the positive element of a voltaic couple.

The negative element of a voltaic couple is protected by the presence of the positive element, which is alone corroded. This method has been adopted with considerable success to

electrically protect metals from corrosion. A few examples will suffice. (See *Cell, Voltaic.*)

(1) Davy proposed to protect the copper sheathing of ships from corrosion by attaching pieces of zinc to the copper sheathing. This succeeded too well since the copper salts which were formerly produced and acted as a poison to the marine plants and animals, being now absent, permitted these forms of life to thrive to such an extent as to seriously foul the ship's bottom.

(2) A ring of zinc attached to a lightning rod, near its points has, it is claimed, the power of protecting the points from corrosion.

(3) Iron bars of railings, if sunk or embedded in zinc, are preserved from corrosion near the junction of the two metals, but if sunk in lead are rapidly corroded, because iron is electro-positive to lead, but electro-negative to zinc.

(4) Tinned iron rapidly corrodes or rusts when the iron is exposed to the atmosphere by a scratch or abrasion, because the iron is electro-positive to tin. Nickel-plated iron, for the same reason, rusts rapidly on the exposure of an abraded surface.

(5) Zinced or galvanized iron, or iron covered with a deposit of zinc, is protected from corrosion because the zinc, being positive to iron, can alone be corroded, and the zinc is protected in part by the coating of insoluble oxide formed.

Meter, Current ——— —(See *Galvanometer.*)

Meters, Electric ——— —Apparatus for measuring commercially, the quantity of electricity that passes in a given time, through any consumption circuit.

Electric meters are constructed of a great variety of forms; they may, however, be arranged under the following heads:

(1) *Electro-Magnetic Meters,* or those in which the current passing is measured by the electro-magnetic effects it produces.

In such meters the entire current may pass through the meter.

(2) *Electro-Chemical Meters*, or those in which the current passing is measured by the electrolytic decomposition it effects.

In these meters, a shunted portion only of the current is usually passed through a solution of a metallic salt, and the current strength determined by the amount of electrolytic decomposition thus effected.

(3) *Electro-Thermal Meters*, or those in which the current passing is measured by a movement effected by the increase in temperature of a resistance through which the current is passed, or by the amount of a liquid evaporated by the heat generated by the current.

(4) *Electric-Time Meters*, or those in which no attempt is made to measure the current that passes, but in which a record is kept of the number of hours that an electric lamp, motor, or other electro-receptive device, is supplied with the current.

Edison's electric meter is of the second class. It consists of two *voltameters*, or electrolytic cells, containing zinc sulphate, in which two plates of chemically pure zinc are dipped. The current that passes is determined by the amount of the variation in weight of the zinc plates. To determine this, the plates are weighed at stated intervals: one plate every month, the other plate, which is intended to act as a check on the first, only once in three months. Some difficulty has been experienced in meters of this class, from the variations in the value of the shunt resistance, due to variations in the condition and temperature of the electrolytic cell. The use of a compensating resistance, however, has, it is claimed, removed this objection.

Methods of Magnetization by Touch.—

These are three, viz.:

(1) *Single Touch.* A Method for effecting the magnetiza-

tion of a bar or other magnetizable material by touch from a single magnet.

In single touch the magnetizing magnet is simply drawn over the bar to be magnetized from end to end and *returned through the air*, the stroke being repeated a number of times. The end of the pole the magnet leaves is thus magnetized oppositely to that of the magnetizing pole.

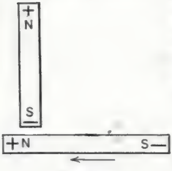


Fig. 283.

By some writers the method of single touch is described as that effected by placing the magnetizing magnet N S, Fig. 283, on the middle of the bar to be magnetized and drawing it to the end and returning through the air as before, and then reversing the pole, placing it on the middle of the bar, and drawing it towards the other end. The former would, however, appear to be the better use of the term *single touch.*

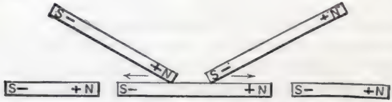


Fig. 284.

(2) *Separate Touch.*

In separate touch two magnetizing bars are placed with their opposite poles at the middle of the bar to be magnetized and drawn away from each other towards its ends, as shown

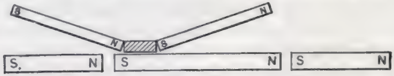


Fig. 285.

in Fig. 284. This motion is repeated a number of times, the poles being returned through the air.

In the above, as in all cases of magnetization by touch,

better effects are produced if the bar to be magnetized is rested on the opposite poles of another magnet, or placed near them, as shown in Fig. 285.

(3) *Double Touch.*

In double touch the two magnets are placed with their opposite poles together on the middle of the bar to be magnetized, as shown in Fig. 285. They are then moved to one end of the bar, *when, instead of removing them and passing them back through the air* to the other end, they are moved in this direction over the bar to be magnetized to the other end, and this motion is repeated a number of times. The motion is stopped at the middle of the bar, when the magnetizing magnets are moving in the opposite direction to that at which they began to move. This assures an equal number of strokes to the two halves of the bar. The method of double touch produces stronger magnetization than either of the other methods but does not effect such an even distribution of the magnetism, and therefore is not applicable to the magnetization of needles.

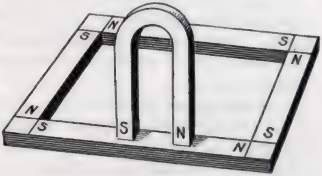


Fig. 286.

A variety of double touch is shown in Fig. 286, where four bars to be magnetized are placed in the form of a hollow rectangle, with only their ends touching at their edges, the angular spaces at the corners being filled with pieces of soft iron. The horseshoe magnet N S, is then moved around the circuit several times in the same direction. This is believed to produce a more uniform magnetization than the ordinary method of double touch.

Methven's Standard Screen.—An upright rectangular plate of metal, furnished with a vertical slot of such dimen-

sions as will permit an Argand burner, the flame of which is three inches high, to send through the slot a light equal to two standard candles.

Metre Bridge.—A slide form of Wheatstone's electric balance, in which the slide wire is one metre in length. (See *Balance, Wheatstone's Slide Form of.*)

Metre Candle. (See *Candle, Metre.*)

Metric System of Weights and Measures.—A system of weights and measures adopted by the French, and by the scientific world generally.

For measures of length, the one ten-millionth part of the quadrant of a meridian of the earth is taken as the unit of length. This unit of length is called a metre, and various subdivisions and multiples of its length are made on the decimal system.

For a system of weights, the weight of one cubic centimetre of pure water at 39.2° F., the temperature of the maximum density of water, is taken as the unit of weight. This is called a *gramme*, and various multiples, and subdivisions of this unit are made on the decimal system.

The following table of French measures and their corresponding English values are taken from Deschanel's "Elementary Treatise on Natural Philosophy":

Length.

1 millimetre = .03937 inch, or about $\frac{1}{25}$ inch.

1 centimetre = .3937 inch.

1 decimetre = 3.937 inches.

1 metre = 39.3707 inches = 3.281 ft. = 1.0936 yd.

1 kilometre = 1093.6 yds., or about $\frac{5}{8}$ mile.

More accurately, 1 metre = 39.370432 in. = 3.2808693 ft. = 1.09362311 yd.

Area.

1 sq. millimetre = .00155 sq. inch.

1 sq. centimetre = .155 sq. inch.
1 sq. decimetre = 15.5 sq. inches.
1 sq. metre = 1550 sq. inches = 10.764 sq. ft. = 1.196 sq. yd.

Volume.

1 cub. millimetre = .000061 cub. inch.
1 cub. centimetre = .061025 cub. inch.
1 decimetre = 61.0254 cub. inches.
Cubic metre = 61025 cub. in. = 35.3156 cub. ft. = 1.308 cub. yd.

The litre (used for liquids) is the same as the cubic decimetre, and is equal to 1.7617 pint, or .22021 gallon.

Mass and Weight.

1 milligramme = .01543 grain.
1 gramme = 15.432 grains.
1 kilogramme = 15432.3 grains = 2.205 lbs. avoir.
More accurately, the kilogramme is 2.20462125 lbs.

Miscellaneous.

1 gramme per sq. centimetre = 2.0481 lbs. per sq. ft.
1 kilogramme per sq. centim. = 14.223 lbs. per sq. in.
1 kilogrammetre = 7.2331 foot-pounds.

1 *force de cheval* = 75 kilogrammetres per second, or 542½ foot-pounds per second, nearly, whereas 1 horse-power (English) = 550 foot-pounds per second.

Conversion of English into French measures:

Length.

1 inch = 2.54 centimetres, nearly.
1 foot = 30.48 centimetres, nearly.
1 yard = 91.44 centimetres, nearly.
1 statute mile = 160933 centimetres, nearly.
More accurately, 1 inch = 2.5399772 centimetres.

Area.

1 sq. inch = 6.45 sq. cm., nearly.
1 sq. foot = 929 sq. cm., nearly.
1 sq. yard = 8361 sq. cm., nearly.
1 sq. mile = 2.59×10^{10} sq. cm., nearly.

Volume.

1 cub. inch = 16.39 cub. cm., nearly.
1 cub. foot = 28316 cub. cm., nearly.
1 cub. yard = 764535 cub. cm., nearly.
1 gallon = 4541 cub. cm., nearly.

Mass.

1 grain = .0648 gramme, nearly.
1 oz. avoir. = 28.35 gramme, nearly.
1 lb. avoir. = 453.6 gramme, nearly.
1 ton = 1.016×10^6 gramme, nearly.
More accurately, 1 lb. avoir. = 453.59265 gm.

Velocity.

1 mile per hour = 44.704 cm. per sec.
1 kilometre per hour = 27.7 cm. per sec.

Density.

1 lb. per cub. foot = .016019 gm. per cub. cm.
62.4 lbs. per cub. ft. = 1 gm. per cub. cm.

Force (assuming g = 981).

Weight of 1 grain = 63.57 dynes, nearly.
" 1 oz. avoir. = 2.78×10^4 dynes, nearly.
" 1 lb. avoir. = 4.45×10^5 dynes, nearly.
" 1 ton = 9.97×10^8 dynes, nearly.
" 1 gramme = 981 dynes, nearly.
" 1 kilogramme = 9.81×10^5 dynes, nearly.

Work (assuming g = 981).

1 foot-pound = 1.356×10^7 ergs, nearly.
1 kilogrammetre = 9.81×10^7 ergs, nearly.
Work in a second by one theoretical "horse power" = 7.46×10^9 ergs, nearly.

Stress (assuming g = 981).

1 lb. per sq. ft. = 479 dynes per sq. cm., nearly.
1 lb. per sq. inch = 6.9×10^4 dynes per cm., nearly.
1 kilog. per sq. cm. = 9.81×10^5 dynes per sq. cm., nearly.

760 mm. of mercury at 0° C. = 1.014×10^6 dynes per sq. cm., nearly.

30 inches of mercury at 0° C. = 1.163×10^6 dynes per sq. cm., nearly. (*Deschanel's Natural Philosophy.*)

Mho.—A term proposed by Sir Wm. Thomson for the practical unit of conductivity.

A mho is such a unit of conductivity as is equal to the reciprocal of one ohm.

The conducting power is equal to $\frac{1}{R}$ *or the reciprocal of the resistance.*

The word *mho,* as is evident, is obtained by inverting the order of sequence of the letters in the word *ohm.*

Micro (as a prefix).—The one millionth; as, a microfarad, the millionth of a farad; a microvolt, the one millionth of a volt.

Micrometer, Arc ——.—An apparatus for the accurate measurement of the length of a voltaic arc by means of a micrometer.

The distance between two carbon electrodes—one movable and the other fixed—placed inside a glass vessel, is accurately determined by means of a micrometer placed on the movable electrode. The operation is similar to that of the *vernier wire-gauge.* (See *Wire-Gauge, Vernier.*)

Microphone.—An apparatus invented by Prof. Hughes for rendering faint or distant sounds distinctly audible.

The microphone depends for its operation on variations produced in the resistance of the circuit of a small battery and receiving telephone by means of a loose contact.

The loose contact may take a variety of forms. Originally, it was made in the form shown in Fig. 287, in which a small piece of carbon E, pointed at both ends, is inserted in holes near the ends of cross pieces of carbon B and C. The thin

upright board A, on which these are supported, acts as a sounding board or diaphragm, and its movements by sound waves is at once audible to a person listening at the receiving telephone. The walking of a fly over the sounding board is heard as a very much louder sound.

The forms of transmitting telephone invented by Reis, Edison, Blake, Berliner and others, are in reality varieties of microphones.

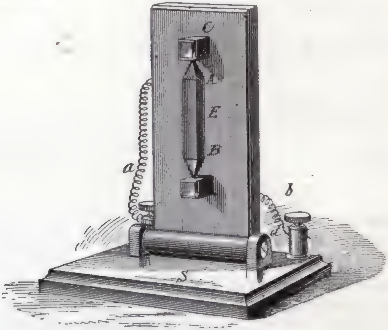


Fig. 287.

Microphone Relay.—A device for automatically repeating a telephone message over another wire.

A form of microphone relay is shown in Fig. 288.

Several minute microphones, mounted on the diaphragm of the telephone whose message is to be repeated, so vary the resistance of a local battery included in their circuit as to automatically repeat the articulate speech received.

The microphones may be connected either in multiple-arc or in series, as shown in Fig. 289.

Microtasimeter.—An apparatus invented by Edison to

measure minute differences of temperature, or of moisture, by the resulting differences of pressure.

A change of temperature, or moisture, is caused to produce variations in the resistance of a button of compressed lamp-black, placed in the circuit of a delicate galvanometer. The

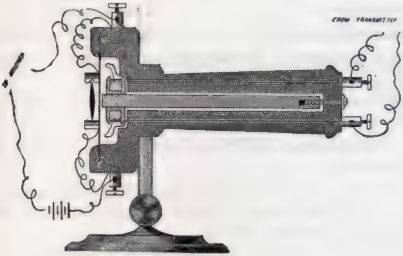


Fig. 288.

apparatus, though of surprising delicacy, is scarcely capable of practical application, from the fact that the resistance of the carbon does not resume its normal value on the removal of the pressure.

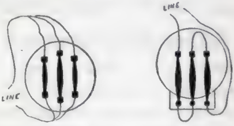


Fig. 289.

Mil.—A unit of length used in measuring the diameter of wires, equal to the $\frac{1}{1000}$ of an inch, or .001 inch.

Mil, Circular ——— —A unit of area employed in measuring the areas of cross sections of wires, equal to .78540 square mil.

One circular mil = .78540 square mil.

The area of cross section of a circular wire one mil in diameter is equal to .78540 square mil. (See *Circular Units, etc.*)

Mil, Square —— —A unit of area employed in measuring the areas of cross sections of wires, equal to .000001 square inch.

One square mil = 1.2732 circular mil.

Milli (as a prefix).—The one-thousandth part.

Milli-Ampère.—The thousandth of an ampère.

Milli-Oerstedt.—The one-thousandth of an Oerstedt.

Mimosa Sensitiva, or Sensitive Plant.—A sensitive plant whose leaves fold or shut up when touched.

The fibres of all the sensitive plants, such for example as the above, the Venus' fly-trap, etc., like *all muscular fibre,* and indeed all *protoplasm, suffer contraction when traversed by electric currents.*

Pouillet concludes from numerous observations that the free positive electricity of the atmosphere is partly due to the vapors disengaged by growing plants.

The peculiar geographical distribution of thunder storms, however, does not favor this assumption.

Mine Exploder, Electro-Magnetic —— —(See *Exploder, Electric. Fuse, Electric.*)

Miophone.—An application, by Boudet, of the *microphone* for the medical examination of the muscles.

Mirror Galvanometer.—(See *Galvanometer, Mirror.*)

Moisture, Effect of —— on Electrical Phenomena.—The presence of moisture on the surfaces of insulators permits the loss or *dissipation of an electric charge.*

This loss is more rapid with *negatively charged bodies* than with those positively charged.

Molar, or Mass Attraction.—(See *Gravitation.*)

Molecular Attraction.—(See *Attraction, Molecular.*)

Molecular Bombardment.—(See *Matter, Radiant or Ultra-Gaseous.*)

Molecular Chain.—A polarized chain of molecules that exists in an electrolyte during its electric decomposition, or in a voltaic cell on closing its circuit. (See *Grothüss' Hypothesis.*)

Molecular Heat.—(See *Heat, Molecular.*)

Molecular Rigidity, or Coercive Force.—(See *Coercive Force.*)

Molecule, Gramme———The weight of any substance taken in grammes numerically equal to the molecular weight.

The gramme molecule represents the number of small *calories* of heat required to raise one gramme of the substance through 1° C. (See *Calorie.*)

Moment of Couples.—(See *Couples, Moment of.*)

Moment, Magnetic—— —(See *Magnetic Moment.*)

Monophotal Arc Light Regulator.—A term sometimes employed to distinguish an arc electric lamp in which the whole current passes through the arc regulating mechanism, and which is usually operated singly in circuit with a dynamo. *Maier.* (See *Polyphotal.*)

Morse Alphabet.—(See *Alphabet, Morse.*)

Morse Recorder, or Register.—(See *Recorder, Morse's.*)

Morse System of Telegraphy.—(See *Telegraphy, Morse.*)

Morse's Telegraphic Sounder.—(See *Sounder, Morse's Telegraphic.*)

Motograph, Electro —— —An apparatus for the electric transmission of signals, in which the receiving instrument is operated by the slipping of a lever over a cylinder of moistened chalk, on the passage of the current. (See *Electro Motograph.*)

The solution for moistening the paper consists of sodium chloride and pyrogallic acid dissolved in water.

Motor, Electric —— —A device for transforming electric power into mechanical power.

All practical electric motors depend for their operation on magnetic attraction or repulsion. The entire magnetism may be produced by the current, or part may be obtained from permanent magnets, and the rest from electro magnets.

A dynamo electric machine will act as a motor if a current is sent through it. Such a motor is sometimes called an *electro motor*. The term electric motor would, however, appear to be the preferable one.

In all cases the rotation is in such a direction as to induce in the armature an electromotive force opposed to that of the driving current, this is therefore called the counter electromotive force.

A Magneto Dynamo, or a dynamo the field of which is obtained from permanent magnets, or a *Separately Excited Dynamo*, will operate as a motor when a current is sent through its armature, and will turn it in the *opposite direction* to that required to drive it in order to produce current.

A Series Dynamo, will operate as a motor when a current is sent through it. If the current is sent through it in the opposite direction to that which it produces when in operation as a *generator*, the polarity of the field is reversed and the dynamo will turn as a motor in the *opposite direction* to that required to produce the current. If the current is reversed the polarity of both the field and the armature is again reversed, and the dynamo still rotates as a motor in the *opposite direction* to that in which it is rotated as a generator.

A series dynamo, therefore, always rotates as a motor in a direction opposite to that of its rotation as a generator.

When, however, the polarity of the field only is reversed by changing the connection between the armature and the field, the rotation is in the same direction.

A Shunt Dynamo operated as a motor will also turn in but one direction, *but this direction is the same as that in which it turns when operating as a generator;* for, if the direction

of the current in the armature is the same as in a generator, that in the shunt is reversed.

A Compound-Wound Dynamo will move in a *direction opposite* to that of its motion as a generator if the series part is more powerful than the shunt, and in the *same direction* if the shunt part is more powerful than the series. To use a compound-wound dynamo as a motor it is necessary merely to reverse the connections of the series coils.

Alternating-Current Dynamo.—The current from an alternating-current dynamo, if sent through a similar alternating-current dynamo running at the same speed, will drive it as a motor. Such a machine possesses the disadvantage of requiring to be maintained at a speed depending on that of the driving dynamo, and also that it requires to be brought to this speed before the driving current is supplied to it. As a result of this last requirement, variations in the load are apt to stop the motor. Considerable improvements, however, are being introduced into alternate-current motors, by which these difficulties are almost entirely removed.

An alternating current sent through any self-exciting dynamo-electric machine, such as a shunt or series machine, will drive it continuously as a motor. The sudden reversals in the magnetization of its cores will, however, unless they are thoroughly laminated, set up powerful eddy currents that will injuriously heat the machine.

The *Reversibility of any Dynamo-Electric Machine*, or its ability to operate as a motor if supplied with a current, leads to a fact of great importance in the efficiency of electric motors. This fact is that during the rotation of the armature there is induced in it, during its passage through the field of the machine, an electromotive force opposed to that produced in the armature by the driving current, or a *counter-electromotive force*. (See *Spurious Resistance. Counter Electromotive Force.*) This counter electro-motive force acts as a *spurious resistance*, and opposes the passage of the driving

current, so that, as the speed of the electric motor increases, the strength of the driving current becomes less, until, when a certain maximum speed is reached, no current passes. In actual practice, this maximum speed is not attained, or is only momentarily attained, and a small, nearly constant, current is expended in overcoming friction at the bearings, air friction, etc.

When, however, the load is placed on the motor, that is, when it is caused to do work, the speed is reduced and the counter electromotive force is decreased, thus permitting a greater current to pass. The fact that the load thus automatically regulates the current required to drive the motor, renders electric motors very economical in operation.

The relations, between the power required to drive the generating dynamo, and that produced by the electric motor, are such that *the maximum work per second is done by the motor, when it runs at such a rate that the counter electromotive force it produces is half that of the current* supplied to it. The maximum work or activity of an electric motor is therefore done when its theoretical efficiency is only 50 per cent. This, however, must be carefully distinguished from the maximum efficiency of an electric motor. A maximum efficiency of 100 per cent. can be attained theoretically, and, in actual practice, considerably over 90 per cent. is obtained. In such cases, however, the motor is doing work at less than its *maximum power*.

An efficiency of 100 per cent. is reached when the counter electromotive force of the motor is equal to that of the source supplying the driving current. Supposing now the driving machine to be of the same type as the motor, the two machines *are now running at the same* speed. If now a load is put on the motor so as to reduce its speed, and thus permit it to produce a counter electromotive force of but 90 per cent., its efficiency will be but 90 per cent. In such a case, therefore, the efficiency is represented by the relative speeds of the generator and the motor.

Motor Electromotive Force.—A term proposed by F. J. Sprague for the counter electromotive force of an electric motor. (See *Counter Electromotive Force.*)

This term was proposed by Sprague as expressing the necessity for the existence of a counter electromotive force in an electric motor, in order to permit it to utilize the energy of the electric current which drives it.

Motor, Pyro-Magnetic ——— —(See *Pyro-Magnetic Motor.*)

Mouse-Mill.—A form of *convection induction machine* invented by Sir Wm. Thomson to act as the *replenisher* of his *Electrometer.* (See *Electrostatic Induction Machines. Replenisher.*)

Mouse-Mill Dynamo, Sir Wm. Thomson's ——— —— ——— —A dynamo electric machine designed by Sir Wm. Thomson, named from the resemblance of its armature to a mouse mill.

The armature conductor of this dynamo consists of parallel bars of copper, arranged on a hollow cylinder like the bars on a mouse-mill.

Mouth Pieces.—Openings into air-chambers, generally circular in shape, placed over the diaphragms of telephones, phonographs, gramophones, or graphophones to permit the application of the voice in speaking so as to set the diaphragm into vibration.

The mouthpiece may also be utilized by the ear of an observer listening so as to be affected by its vibrations.

Mover, Prime ——— —In a system of distribution of power the motor by which the others or *secondary movers are driven.*

In a steam plant the steam engine is the *prime mover;* the shafts or machines driven by the main shafts are sometimes called the *secondary movers.* The main shaft is called the

driving shaft. Its motion is carried by means of *belts* to other shafts called *driven shafts.* The belt passes over *pulleys* on the *driving* and *driven shafts.* They are called respectively the *driving* and *driven pullies.*

Multiple-Arc Circuit.—(See *Circuits, Varieties of.*)

Multiple-Series, Circuit.—(See *Circuits, Varieties of.*)

Multiple Switch Board.—(See *Board, Multiple Switch.*)

Multiplex Telegraphy.—A system of telegraphy in which more than four messages can be simultaneously transmitted over a single wire, either all in the same direction, or part in one direction, and the remainder in the opposite direction. (See *Telegraphy, Multiplex.*)

Multiplier, Schweigger's-—— —(See *Galvanometer.*)

Mutual Induction.—(See *Induction, Mutual.*)

Muscles, Electrical Excitation of—— —(See *Electrotonus.*)

Muscular Pile, Matteucci's—— —A voltaic battery or pile, the elements of which are formed of longitudinal and transverse sections of muscle, alternately connected.

Matteucci's experiments appear to show that the lower the animal is in the scale of creation, the stronger is the current produced, and the longer its duration. Du Bois-Reymond has shown that the muscular current is not due *to contact*, but to the differences of electric potential naturally possessed by the muscles themselves.

The nerves also possess the power of producing differences of electromotive forces and hence currents. (See *Electrotonus.*)

Musket, Electric—— —A gun in which the charge is ignited by the incandescence of a platinum wire by the action of a battery placed in the body of the gun.

Myria (as a prefix).—A million times.

Nascent State.—A term used in chemistry to express the state or condition of an elementary atom or radical just liberated from chemical combination, when it possesses chemical affinities or attractions more energetic than afterwards.

According to Grothüss' hypothesis, during the decomposition of a chain of polarized molecules, such for example as that of hydrogen sulphate, $H_2 SO_4$, in a zinc-copper voltaic cell the two atoms of hydrogen H_2, liberated by the combination of the SO_4, with an atom of zinc Zn, possess a stronger affinity for the SO_4 of the molecule next to it, than does its own H_2, and thus liberates its two atoms of hydrogen, which in turn unite with the SO_4, of the next molecule in the polarized chain, and this continues until the two atoms of hydrogen liberated from the last molecule in the chain are given off at the surface of the copper plate. (See *Grothüss' Hypothesis.*)

The nascent state of elements is doubtless due to the fact that the elements are then in a *free state,* with their *bonds open* or *unsatisfied,* and therefore possess greater affinities than when they are united in molecules. Thus H —, H —, or *atomic hydrogen,* should possess different affinities than H —H, or *molecular hydrogen.*

Natural Currents.—(See *Earth Currents.*)

Natural Law.—(See *Law, Natural.*)

Natural Magnet.—(See *Lodestone. Natural Magnet.*)

Needle, Astatic ——— —A system of two horizontal magnetic needles, with the opposite poles facing each other, rigidly attached to a vertical support, on which they are free to turn. (See *Astatic Needle.*)

The use of an astatic needle lessens the force required to deflect the needle either in the earth's field, or in the field of another magnet. An astatic needle is shown in Fig. 290.

Needle, Dipping ——— —A magnetic needle, suspended so as to be free to move in a vertical plane, employed to determine the deviation of the needle from a horizontal

position, or the *angle of dip*, or *magnetic inclination* of a place. (See *Dip, Magnetic. Inclination, Magnetic. Inclinometer. Inclination Chart.*)

Needle, Magnetic ——— —(See *Compass, Azimuth.*)

Needle of Oscillation.—A small magnetic needle employed for measuring the intensity of a magnetic field by counting the number of oscillations the needle makes in a given time, when disturbed from its position of rest in such field. (See *Intensity of Magnetization. Isodynamic Lines.*)

Needle, Telegraphic ——— —A needle employed in telegraphy, the movements of which to the *left* or *right* respectively, represent the dots and dashes of the Morse alphabet. (See *Telegraphy, Needle System.*)

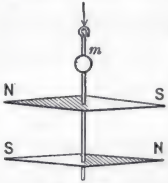


Fig. 290.

Negative Electricity.—One of the phases or states of electric excitement.

An electrically charged body, no matter from what source it has received its charge, manifests either a *negative* or a *positive charge.*

According to the *Double Fluid Hypothesis*, each of these phases, or varieties of electric excitement, is caused by the presence of a distinct and separate fluid, endowed with characteristic properties.

According to the *Single Fluid Hypothesis, negative electricity* is caused by the *deficit* of a *single* fluid, and positive electricity by a *surplusage* of the same fluid.

According to another view, negative electricity is caused by an *excess* of the universal ether, and positive electricity by its *deficit.* (See *Hypotheses of Electricity.*)

Negative Element or Plate, of a Voltaic Cell.—That element or plate of a voltaic cell into which the current passes from the exciting liquid of the cell.

The plate that is not acted on by the electrolyte during the generation of current by the cell. The copper, or carbon plate respectively in a *zinc-copper*, or *zinc-carbon* couple.

It must be carefully borne in mind that the conductor attached to the *negative element of a voltaic pile, is the positive conductor or electrode of the pile*, since the current that flows into the plate from the liquid or electrolyte, must flow out of the plate where it projects beyond the liquid.—(See *Cell, Voltaic, Polarity of.*)

Nerve Fibre, Electric Excitability of ——— —(See *Excitability, Electric, of Nerve Fibre.*)

Nerves, Action of Electricity on ——— —(See *Electrotonus. Galvanization. Fardization. Galvano-Faradization.*)

Net, Faraday's ——— —An insulated net of cotton gauze, or other similar material, capable of being turned inside out, without being thereby discharged, employed for demonstrating that in a charged, insulated conductor, the entire charge is accumulated on the outside of the conductor.

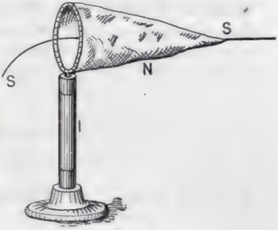


Fig. 291.

Faraday's net, as shown in Fig. 291, consists of a bag N, of cotton gauze, or mosquito netting, supported on an insulating stand I. When tested by a proof plane, no free electric charge is found on the inside, though such a charge is readily detected by the same means on the outside. By means of the silk strings S, S, the bag can be turned inside out, when the charge will then all be found on the then inside or now outside.

Faraday was in the habit of protecting his delicate electroscopes against outside electrification by covering them with

gauze. To properly act as an electric screen, the gauze should be connected with the earth.

Faraday constructed a small insulated room, twelve feet in height, breadth, and depth, covered inside with tin-foil, and. on charging this room from the outside, he was unable to detect the presence of the charge, even by the aid of his most delicate instruments. This room is often called *Faraday's Cube.*

Network of Currents.—A term sometimes applied to a number of *shunt* or *derived circuits.* (See *Shunt or Derived Circuits. Kirchoff's Law.*)

Neutral Line of Commutator Cylinder.—(See *Line, Neutral, of Commutator Cylinder.*)

Neutral Points of a Dynamo Electric Machine.—Two points of greatest difference of potential, on the commutator cylinder, situated at the opposite ends of a diameter thereof, at which the collecting brushes must rest in order to carry off the current quietly.

These are called the neutral points because the coils that are short circuited by the brushes lie in the magnetically neutral points of the armature. (See *Line, Neutral, of Commutator Cylinder.*)

Neutral Points of Thermo-Electric Diagram.—The points on a *thermo-electric diagram* where the lines representing the *thermo-electric powers* of any two metals cross each other.

A mean temperature for any two metals in a *thermo-electric series,* at which, if their two junctions are slightly over and slightly under the mean temperature (the one as much above as the other is below), no differences of electromotive force are developed. (See *Diagram, Thermo-Electric. Couple, Thermo-Electric.*)

Neutral Points on a Magnet.—Points approximately midway between the poles of a magnet. (See *Line, Neutral, of Magnet. Equator of Magnet.*)

Nickel Bath.—(See *Baths, Nickel, etc.*)

Non-Conductors. Insulators.—Substances that offer considerable resistance to the passage of an electric current through their mass.

There are no substances known that absolutely prevent the flow of an electric current, the difference of potential of which is sufficiently great. (See *Conductors, Table of.*)

Notation, Algebraic ——— —A system of arbitrary symbols employed in algebra.

The following brief description of the notation employed in algebra is for the use of the non-mathematical reader:

Quantities are represented in algebra by letters, such as a and b, x, and y, etc.

Addition is represented thus, $a + b$.

Subtraction is represented thus, $a - b$.

Multiplication is represented thus, $a \times b$, or simply by writing the letters next to each other ab.

Division is represented thus, $a \div b$, or $\frac{a}{b}$.

An Exponent, or figure placed *to the right* of a letter, *above* it as a^3, indicates that the *quantity* represented by a, is to be *multiplied* by itself three times, as $a \times a \times a$, or $a\,a\,a$.

A Coefficient, or figure placed *to the left* of a quantity, indicates the number of times that quantity is to be taken; thus, $3\,a$, indicates that a is to be *added* three times, thus $a + a + a$, or $3 \times a$.

A *Radical Sign or Root*, thus $\sqrt{}\, a$, or $\sqrt[2]{}\, a$, indicates that the square root of the quantity a, is to be taken. In the same manner $\sqrt[3]{}\, a$, indicates that the cube root of a is be taken.

These expressions are sometimes written $a^{\frac{1}{2}}$, or $a^{\frac{1}{3}}$.

Equality is indicated thus: $a^3 = a \times a \times a$, or $a^{\frac{1}{2}} = \sqrt{a}$.

A negative exponent a^{-2} indicates $\frac{1}{a^2}$, or is the exponent of the reciprocal of the quantity indicated.

Null or Zero Methods.—Methods employed in electrical measurements, in which the values of the electromotive force in *volts*, the resistance in *ohms*, or the *current in ampères*, or other similar units, are determined by balancing them against equal values of the same units, and ascertaining such equality, not by the *deflections* of the needle of a galvanometer, or of an electrometer, but by the *absence of such deflections.*

The advantage of zero-methods is found in the fact that the galvanometer or electrometer may then be made as sensitive as possible, which is not always the case, since great deflections are generally to be avoided, especially in tangent galvanometers.—(See *Galvanometers. Electrometers.*)

Number, Diacritical———— —(See *Diacritical Number.*)

Observatory, Magnetic ———— —An observatory in which observations of the variations in the direction and intensity of the earth's magnetic field are made.

Magnetic observatories are generally furnished with self-registering magnetic apparatus such as *magnetographs, magnetometers, inclinometers.* (See *Magnetometer. Magnetograph. Inclinometer.*)

Magnetic observatories are generally constructed entirely of non-magnetic materials, that is, of such materials as are destitute of *paramagnetic properties.*

Occlusion of Gases.—The absorption or shutting up of a gas in the pores, or on the surfaces of various substances.

Carbon possesses in a marked degree the property of *occluding* or *absorbing* gases in its pores. These occluded gases must be driven out from the carbon conductor employed in an incandescent lamp, since otherwise their expulsion, on the incandescence of the carbon consequent on the lighting

of the lamp, will destroy the high vacuum of the lamp chamber, and thus lead to the ultimate destruction of the lamp. (See *Lamp, Electric Incandescent.*)

Odorscope.—An apparatus in which the determination of an odor was attempted by the measurement of the effect the odorous vapor, or effluvia, produced on a variable contact resistance.

The *microtasimeter* was used in connection with the odorscope. (See *Diagometer. Microtasimeter.*)

Oerstedt, An ——— —A proposed term for the unit of electric current, in place of an ampère.

The term has not been adopted.

Ohm—The unit of electric resistance.

Such a resistance as would limit the flow of electricity under an electro-motive force of one *volt* to a current of one *ampère*, or to *one coulomb per second.* (See *B.A. Unit. Legal Ohm. Standard Ohm.*)

Ohm, Legal ——— —(See *Legal Ohm*)

Ohmic or True Resistance.—The *true resistance* of a conductor due to its dimensions, and specific conducting power, as distinguished from the *spurious resistance* produced by a counter electromotive force. (See *Counter Electromotive Force. Motors, Electric. Resistance, Spurious.*)

Ohmmeter.—A commercial galvanometer, devised by Ayrton, for directly measuring the resistance of any part of a circuit through which a strong current is flowing, by the deflection of a magnetic needle.

Ayrton's *ohmmeter* is represented diagrammatically in Fig. 292. Two coils C C, and *c c*, of a short thick wire, and of a long thin wire, respectively, are placed at right angles to each other, and act on a *soft iron needle* situated as shown. The short thick wire coil C C, is connected in *series* with the resistance O, to be measured. The large fine wire coil, of *known high resistance,* is placed as a shunt to the unknown resistance.

Under these circumstances, it can be shown that the action on the needle is due to the ratio of the difference of potential at the terminals of the unknown resistance, and the current strength in the thick wire coil, or, $R = \frac{E}{C}$, as may be deduced from Ohm's law.

The coils are so proportioned that the current when flowing

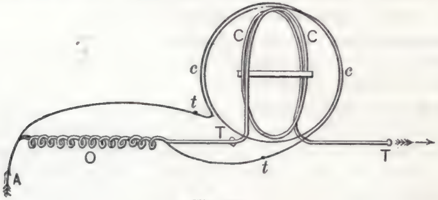


Fig. 292.

through the short thick wire moves the needle to the zero of the scale, while the long thin wire produces a deflection directly proportional to the resistance.

Ohm's Law.—*The strength of the current in any circuit, is directly proportional to the difference of potential, or electromotive force in that circuit, and inversely proportional to the resistance of the circuit, i. e., is equal to the quotient arising from dividing the electromotive force by the resistance.*

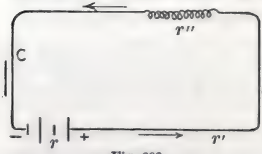


Fig. 293.

Ohm's law is expressed algebraically, thus:

$$C = \frac{E}{R}.$$

If the electro-motive force is given in *volts*, and the *resistance* in *ohms*, the formula will give the current strength directly in *ampères*.

The resistance of any electric circuit, as for example that shown in Fig. 293, consists of three parts, viz.:

(1) The resistance of the *Source*, r.

(2) That of the *Conducting Wires* or *Leads*, r', and

(3) That of the *Electro-Receptive* Device, r'', energized by the current. Ohm's law applied to this case would be

$$C = \frac{E}{r + r' + r''}.$$

That is, the resistance of the entire series circuit is equal to the sum of the separate resistances.

$$\text{Since } C = \frac{E}{R}, \ (1); \text{ then } E = C\,R, \ (2); \text{ and } R = \frac{E}{C}, \ (3).$$

But, since a current of one ampère is equal to one *coulomb per second*, then, in order to determine in coulombs the quantity of electricity passing in a given number of seconds, it is only necessary to multiply the current by the time in seconds, or $Q = C\,T$, (4).

Hence, referring to the above equations (1), (2), (3) and (4), according to Ohm's law,

(1) The current in ampères is equal to the electromotive force in *volts* divided by the resistance in *ohms*.

(2) The electromotive force in *volts* is equal to the product of the current in *ampères*, and the resistance in *ohms*.

(3) The resistance in *ohms* is equal to the electromotive force in *volts* divided by the current in *ampères*.

(4) The *quantity* of electricity in *coulombs*, is equal to the current in *ampères* multiplied by the time in seconds.

Open Circuit.—(See *Circuit, Broken.*)

Optical Strain.—A deformation or alteration of volume produced in a plate of glass, or other transparent medium, by the action of any stress.

The effect of this strain is shown by the action of the medium on a beam of *plane polarized light.*

Optical Strain, Electro-Magnetic —— —A strain produced in a plate of glass or other transparent medium by placing it in a magnetic field. (See *Electro-Magnetic Stress. Magneto-Optic Rotation.*)

Optical strain, whether electrostatic or magnetic, or even mechanical, often causes a medium to acquire the power of *double refraction,* or *rotary polarization.* (See *Double Refraction, Electric. Magneto Optic Rotation.*)

Optical Strain, Electrostatic —— —A strain produced in a plate of glass, or other transparent solid, by subjecting it to the stress of an electrostatic field. (See *Electrostatic Stress.*)

To obtain the electrostatic stress, holes are drilled in the plate of glass, and wires from a *Holtz machine* or *induction coil* placed therein, the wires being separated by a thin layer of glass. The glass, on being traversed by a beam of plane polarized light, rotates the plane of its polarization in the same direction as the glass would if subjected to a *strain in the direction of the lines of electric force.* (See *Magneto-Optic Rotation.*)

Optics, Electro —— —That branch of electricity which treats of the general relations that exist between light and electricity.

The phenomena of electro-optics may be arranged under the following heads, viz.:

(1) *Electrostatic Stress,* produced by an electrostatic field, causing an optical strain in a transparent medium, whereby such medium acquires either the property of rotating the plane of polarization of a beam of plane polarized light, or of doubly refracting light.

(2) *Electro-Magnetic Stress,* produced by a magnetic field causing an optical strain in a transparent medium, whereby such medium acquires either the property of rotating the

plane of polarization, or of doubly refracting light. (See *Polarization of Light. Double Refraction, Electric.*)

(3) Changes in the electric resistance of bodies caused by the action of light. (See *Selenium Cell.*)

(4) The relation existing between the values of the *index of refraction* of a transparent medium and its *specific inductive capacity.* (See *Refraction. Specific Inductive Capacity.*)

This relation has been shown to be as follows:

The specific inductive capacity is approximately equal to the square of the index of refraction.

(5) The relation existing between the velocity of light and the value of the ratio of the electrostatic and the electro-magnetic units, thus giving a basis for an *electro-magnetic theory of light.* (See *Light, Electro-Magnetic Theory of.*)

Ordinates, Axis of ——— —(See *Abscissas, Axis of.*)

Ores, Electric Treatment of ——— —(See *Furnaces, Electric.*)

Organ, Electric ——— — A wind organ, in which the escape of air into the different pipes is electrically controlled.

In an electric organ the keys, instead of operating levers as usual to admit the passage of air into the pipes, merely make the circuit of a battery through a series of controlling electro-magnets. With such an arrangement, the keyboard can be placed at any desired distance.

Electric organs have been constructed, in which a chemical or mechanical record is made of the notes struck by the performer, as well as the musical value of these notes. By such a device the musical creations of a composer are permanently recorded in characters that are capable of interpretation by a compositor skilled in musical notation.

Oscillating Discharge.—(See *Discharge, Oscillating.*)

Oscillating Needle.—(See *Needle of Oscillations.*)

Oscillation, Centre of ———.—The point, in a body supported so as to swing like a pendulum, which is neither accelerated nor retarded during its oscillations.

The centre of oscillation is always below the centre of gravity. The vertical distance between the centre of oscillation and the point of support of a pendulum, determines the *virtual length* of the pendulum and hence, its number of vibrations per second. (See *Pendulum, Laws of.*)

Oscillations Electric ———————.—The series of partial, intermittent discharges, of which the apparent instantaneous discharge of a Leyden jar through a small resistance actually consists.

These partial discharges produce a series of electric oscillations of the current in the circuit of the discharge, which consist of a true to and fro, or backward and forward motion of the electricity.

Osmose.—The unequal mixing of liquids of different densities through the pores of a separating medium.

If a solution of sugar and water be placed in a bladder, the neck of which is tied to a straight glass tube, and the bladder is then immersed in a vessel of pure water with the tube in a vertical position, the two liquids will begin to mix, the sugar and the water passing through the bladder into the pure water, and the pure water passing into the sugar and water in the bladder. This latter current is the stronger of the two, as will be shown by the water *rising* in the vertical glass tube.

The stronger of the two currents is called the *endosmotic current*, and the weaker the *exosmotic current.*

Osmose, Electric ————.—A difference of liquid level produced in two liquids placed on opposite sides of a diaphragm on the passage of a strong electric current through the liquids between two electrodes placed therein.

The higher level is on the side towards which the current flows through the diaphragm, thus apparently indicating an

onward motion of the liquid with the current, or in other words, the liquid is higher about the *kathode* than the *anode*. The difference of level is the more marked when poorly conducting liquids are employed.

As a converse of this, Quincke has shown that electric currents are set up when a liquid is forced by pressure through a porous diaphragm. The term *diaphragm currents* has been proposed for these currents. Their electro-motive force depends on the nature of the liquid, on the material of the diaphragm, and on the pressure that forces the liquid through the diaphragm. (See *Electro-Capillary Phenomena.*)

Output of Dynamo-Electric Machines.—The electric power of the current generated by a dynamo-electric machine expressed in *volt-ampères*, or *watts.*

S. P. Thompson suggests that dynamo-electric machines be rated as to their practical safe capacity in *units of output of 1,000 watts*, or one *kilo-watt.* According to this, an 8-unit machine might give, say 100 ampères at a difference of potential of 80 volts, or 2,000 ampères at a difference of potential of four volts. Such a unit would be far more expressive than the usual method of rating a machine as having a capacity of such and such a number of lights.

Overtones.—Additional, faint tones, accompanying nearly every distinct musical tone, by the presence of which its peculiarity or quality is produced. (See *Quality, or Timbre.*)

Ozone.—A peculiar modification of oxygen which possesses more powerful oxydizing properties than ordinary oxygen.

Ozone is now generally believed to be tri-atomic oxygen, or oxygen in which the bonds are closed, thus :

The peculiar smell observed when a torrent of sparks

passes between the terminals of a Holtz machine, or a Ruhmkorff coil, is caused by the ozone thus formed.

In a similar manner ozone is formed in the atmosphere during the passage through the air of a flash of lightning.

During the so-called electrolysis of water, some of the oxygen is given off in the form of ozone. The volume of the oxygen liberated is, therefore, somewhat less than half the volume of the hydrogen.

Palladium.—A metal of the platinum group.

Metallic palladium has a tin-white color, and, when polished, a high metallic lustre. It is tenacious and ductile, and, like iron, can be welded at a white heat. It is very refractory and possesses in a marked degree the power of absorbing or occluding hydrogen and other gases. It is not affected by oxygen at any temperature, nor readily affected by ordinary corrosive agents.

Palladium Alloys.—Alloys of palladium with other metals.

Palladium forms a number of useful alloys with various metals. Some of the alloys are as elastic as steel, are unaffected by moisture or ordinary corrosive agencies, *and are entirely devoid of paramagnetic properties.*

These properties have been utilized by their discoverer, Paillard, in their employment for the hair-springs, escapements and balance wheels of watches, in order to permit the watches to be carried into strong magnetic fields without any appreciable effects on the rate of the watch. A number of careful tests made by the author, by long continued exposure of watches, thus protected by the Paillard alloys, in extraordinary fields, show that the protection thus given the watches enables them to be carried into the strongest possible magnetic fields without appreciably affecting their rate.

The Paillard palladium alloys have the following composition, viz.:

Alloy No. 1.

Palladium	60 to 75 parts.
Copper	15 to 25 "
Iron	1 to 5 "

Alloy No. 2.

Palladium	50 to 75 "
Copper	20 to 30 "
Iron	5 to 20 "

Alloy No. 3.

Palladium	65 to 75 "
Copper	15 to 25 "
Nickel	1 to 5 "
Gold	1 to 2½ "
Platinum	½ to 2 "
Silver	3 to 10 "
Steel	1 to 5 "

Alloy No. 4.

Palladium	45 to 50 "
Silver	20 to 25 "
Copper	15 to 25 "
Gold	2 to 5 "
Platinum	2 to 5 "
Nickel	2 to 5 "
Steel	2 to 5 "

The great value of these alloys, when employed for the hair-springs of watches, arises not only from their non-magnetizable properties, and, their inoxidizability, but particularly from the fact that their elasticity is approximately the same for comparatively wide ranges of temperature.

Pane, Magic ——— — A sheet of glass covered with pieces of tin foil with small spaces between them pasted in some design on the glass.

On the discharge of a Leyden jar through these metallic

pieces, the design is seen as a series of minute sparks that bridge the spaces between the adjacent pieces of foil.

Pantelegraphy, or Facsimile Telegraphy.—A system for the telegraphic transmission of charts, diagrams, sketches or written characters. (See *Telegraphy, Facsimile.*)

Paper Carbons.—Carbon, of textile or fibrous origin, obtained from the carbonization of paper.

The carbonization of paper is readily effected by submitting it to the prolonged action of a high temperature while out of contact with air.

For this purpose the paper is packed in retorts or crucibles, and covered with lamp-black, or powdered plumbago, in order to exclude the air.

Since paper consists of a plane of material uniformly thin in one direction, formed almost entirely of fibres of pure cellulose, the greatest length of which extend in a direction nearly parallel to that in which the paper is uniformly thin, it is clear that sheets of this substance, when carbonized, should yield flexible carbons of unusual purity and electrical homogeneity, since such carbons are structural in character, and are uniformly affected by the heat of carbonization, to an extent that would be impossible by the carbonization of any material in a mass.

Paper Perforator.—An apparatus employed in systems of *automatic telegraphy* for punching in a fillet of paper, circular or elongated spaces that produce the dots and dashes of the Morse alphabet, when the fillet is drawn between metal terminals that form the electrodes of a battery. (See *Telegraphy, Automatic.*)

Parabolic Reflector.—A reflector, or mirror, the reflecting surface of which is a paraboloid, or such a surface as would be obtained by the revolution of a parabola about its axis.

A parabolic curve, which may be regarded as a section of a parabola, is shown in Fig. 294. A parabola has the following properties : If lines F P, F P, etc., be drawn from the point F, called the focus, to any point, P, P, etc., in the curve, and the lines P*p*, P*p*, P*p*, etc., be then drawn severally parallel to the axis, V M, then all such angles, F P*p*, F P*p*, will be bisected by verticals to tangents at the point P, P, and P.

Therefore, if a light be placed at the focus of a parabolic reflector, all the light reflected will pass off sensibly parallel to the axis V M.

In locomotive head lights, a lamp is placed at the focus of a parabolic reflector, and the parallel beam so obtained utilized for the illumination of the track. In a *search light*, an electric arc lamp is placed in a parabolic reflector, or at the focus of a lens.

A parabolic reflector, such as is used for search lights, is shown in Fig. 295. A focussing arc lamp must be used for this purpose, so as to maintain the voltaic arc at the focus of the parabolic reflector, notwithstanding the consumption of the carbons.

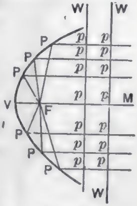


Fig. 294.

Paraffine.—The name given to various solid hydrocarbons, of the marsh-gas series, that are derived from coal oil or petroleum by the action of nitric acid.

Parafine possesses excellent powers of insulation, and forms a good dielectric medium. Dried wood, boiled in melted paraffine, forms a fair insulating material.

Paragrêles.—Lightning rods, intended to protect fields against the destructive action of hail. (See *Hail, Assumed Electrical Origin of.*)

It was formerly believed that hail is caused by electricity. It is now generally believed that the electricity in hail storms is caused by the hail. It will therefore readily be understood that *paragrêles* can afford no real protection.

Parallax.—The apparent angular displacement of an object when seen from two different points of view.

In reading the exact division on a scale to which a needle points, care must be taken to look directly down on the needle, and not sideways, so as to avoid the error of displacement due to *parallax*.

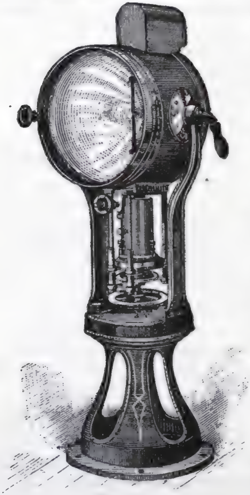


Fig. 295.

Parallel Circuit.—A name sometimes applied to circuits connected in *multiple-arc*. (See *Circuits, Varieties of*.)

Parallelogram of Forces.—(See *Forces, Parallelogram of*.)

Paramagnetic. — Substances possessing the properties ordinarily recognized as magnetic.

Substances possessing the power of concentrating the lines of magnetic force on them.

Paramagnetic is a term employed in contra-distinction to *diamagnetic*. (See *Diamagnetic*.) A paramagnetic substance, cut in the form of a bar whose length is much greater than its breadth and thickness, when suspended in a magnetic field in the manner shown in Fig. 296, will take up a position of rest with its *greatest length* in the *direction of the lines of force*, i. e., will point *axially*. In other words the lines of force will so pass through the paramagnetic substance as to reduce the *magnetic resistance* of the circuit as much as possible.

Paramagnetic substances, therefore, concentrate the lines of force on them. (See *Resistance, Magnetic.*)

Diamagnetic substances, on the contrary, placed as shown in Fig. 296, assume a position of rest with their *least dimensions in the direction of the lines of force*, i. e., they point *equatorially*. This is the position in which they are placed by the lines of force, in order to ensure the *least magnetic resistance* in the circuit of these lines. The magnetic resistance of diamagnetic substances is great as compared with that of paramagnetic substances.

The term *ferro-magnetic* has been proposed for *paramagnetic*. If another term be required, which is doubtful, *sidero-magnetic* proposed by S. P. Thompson, would be far preferable. (See *Ferro-Magnetic. Sidero-Magnetic.*)

Tyndall believes that the magnetic polarity possessed by diamagnetic substances is a distinct polar force, different in its nature from ordinary magnetiism. (See *Polarity, Diamagnetic.*)

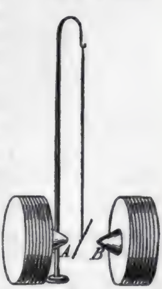


Fig. 296.

Paramagnetism.—The magnetism of a paramagnetic substance.

Parasitical Currents.—(See *Currents, Eddy, Foucault, or Local.*)

Paratonnères.—A French term for lightning rods, sometimes employed in English technicai works.

Lightning rod would appear to be the preferable term.

Partial Earth. (See *Earths.*)

Passive State.—The condition of a metallic substance in which it may be placed in liquids that would ordinarily

chemically combine with it, without being attacked or corroded.

It is very doubtful whether metallic bodies can be properly regarded as possessing an actual passive state. Iron, for example, which is one of the metals that is said to be capable of assuming this so called *passive state*, can be placed in this condition by immersing it for a few moments in concentrated nitric acid, and subsequently washing it. It will then, unlike ordinary iron, neither be attacked by concentrated nitric acid, nor will it precipitate copper from its solutions. This condition is now generally believed to be due to the formation of a thin coating of magnetic oxide on its surface.

Many of the instances of the so-called passive state are simply cases of the well known electrical preservation of metals that form the negative element of a voltaic combination, under which circumstances the positive element only of the voltaic couple is chemically attacked by the electrolyte. (See *Cell, Voltaic. Metals, Electrical Preservation of.*)

P. D. or p. d.—A contraction frequently employed for difference of potential. (See *Difference of Potential.*)

Peltier Effect.—(See *Effect, Peltier.*)

Pendulum, Electric —— —A pendulum so arranged that, in its to-and-fro motions, it sends electric impulses over a line, either by making and breaking contacts, or such in which the to and fro movements are maintained by electric impulses.

Such pendulums are employed in systems for the electrical distribution of time.

Sometimes, instead of using true pendulums for such purposes, coils, or contact points, mounted on the ends of flexible bars of steel called *reeds*, or on tuning forks, are often used for the purpose of establishing currents, or modifying the currents that are already passing in a circuit. The movement of a magnetic diaphragm, as in the case of a telephone

diaphragm, towards and from a coil of wire is another illustration of an electric pendulum.

Pendulum, Laws of ——————.—The laws which express the peculiarities of the motion of a simple pendulum.

A simple pendulum is one in which the entire weight is considered as concentrated at a single point, suspended at the end of a weightless, inflexible, and inextensible line.

The following are the laws of the simple pendulum :

(1) Oscillations of small *amplitude* are approximately *isochronous;* that is, are made in times that are sensibly equal. (See *Amplitude of Vibration. Isochronism.*)

(2) In pendulums of different lengths, the duration of the oscillations is proportional to the square root of the length of the pendulum.

(3) In the same pendulum, the length being preserved invariable, the duration of the oscillation is inversely proportional to the square root of the intensity of gravity.

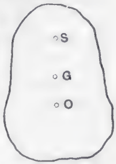


Fig. 297.

The *intensity of gravity* at any latitude, may be determined by the number of oscillations of a pendulum of a given length. In the same manner the *intensity of a magnetic field*, or the *intensity of magnetization* of a magnet, may be determined by the *needle of oscillation*, by observing the number of oscillations a needle makes in a given time when disturbed from its position of rest. (See *Needle of Oscillation.*)

Since a simple physical pendulum is a physical impossibility, the *virtual length* of a pendulum, that is, the vertical distance between its point of support to the *centre of oscillation* is taken as the true length of the pendulum.

If the irregularly shaped body, shown in Fig. 297, whose centre of gravity is at G, is made to swing like a pendulum, either on S, or O, its oscillations will be performed in equal times, and

the body will act as a simple pendulum, whose virtual length is S O.

If, while suspended at S, it be struck at O, it will oscillate around S, without producing any pressure on the supporting axis at S, on which it turns. If floating entirely submerged in a liquid, a blow at O would cause it to move in a straight line, in the direction of the blow, without rotation.

The point O, is called the *centre of percussion*, or the *centre of oscillation*. The centre of oscillation is always below the *centre of gravity*.

Pen, Electric ——— —A device for manifold copying, in which a sheet of paper is made into a stencil by minute perforations obtained by a needle driven by a small electric motor. The stencil is afterwards employed in connection with an inked roller for the production of any required number of copies.

Mechanical pens are constructed on the same principle, the perforations being obtained by mechanical instead of by electric power.

Percussion, Centre of ——— —That point in a body, suspended so as to move as a pendulum at which a blow would produce rotation, but no forward motion, or motion of translation.

Periodicity of Auroras and Magnetic Storms.—Observed coincidences between the occurrence of auroras and magnetic storms, and sun spots.

The periodical occurrence of auroras, or magnetic storms, both as to frequency and intensity, which, occuring at periods of about eleven years apart, corresponds to the well-know *eleven-year sun-spot period.*

It also agrees with a variation in the magnetic declination of a place which, according to Sabine, occurs once in every eleven years.

Permanent Magnet.—(See *Magnet, Permanent.*)

Permanent State of Charge of Telegraph Line.—(See *State, Permanent.*)

Permeability, Magnetic ———— —The ease afforded by any substance to the passage through it of lines of magnetic force.

The magnetic permeability of *paramagnetic* substances is much less than that of *diamagnetic substances.* A substance of great *magnetic permeability* has *small magnetic resistance,* or possesses small *magnetic reluctance* to magnetization. (See *Paramagnetic. Diamagnetic. Magnetic Reluctance.*)

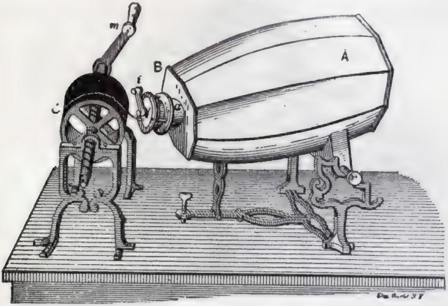


Fig. 298.

Phenomena, Electro Capillary ——— —(See *Electro-Capillary Phenomena.*)

Pherope or Telephote.—(See *Telephote.*)

Phial, Leyden ——— —(See *Jar, Leyden.*)

Philosopher's Egg.—(See *Discharge, Convective.*)

Phonautograph.—An apparatus for the automatic production of a visible tracing of the vibrations produced by any sound.

Phonautographic apparatus consists essentially of devices by which the sound waves are caused to impart their to-and-fro movements to a diaphragm at the centre of which a pencil or tracing point is attached. The record is received on a sheet of paper, or wax, or on a smoked glass or other suitable surface.

Leon Scott's Phonautograph, which is among the forms best known, consists of a hollow conical vessel A, Fig. 298, with a diaphragm of parchment stretched tightly like a drum-head over its smaller aperture B. A tracing point, attached to the

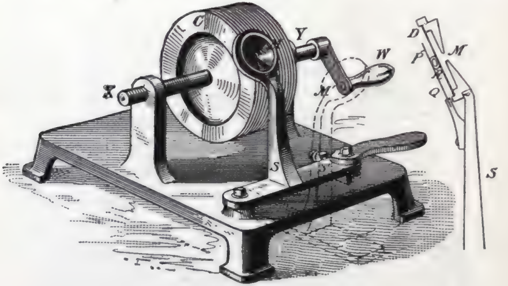


Fig. 299.

centre of the diaphragm, traces a sinuous line on the surface of a soot-covered cylinder C, that is uniformly rotated under the tracing point. As the cylinder is advanced a short distance with every rotation, a sinuous spiral line is traced on the surface.

Phonic Wheel.—A wheel to which is attached a circular table of contact points, that is maintained in synchronous rotation by means of a timed series of electric impulses sent over a line.

The phonic wheel was invented by La Cour, but was first put into successful operation in multiplex telegraphy by Delany in his system of *Synchronous Multiplex Telegraphy.* (See *Telegraphy, Synchronous, Multiplex.*) Delany obtains the exact synchronism of the phonic wheel by a series of correcting electric impulses, automatically sent over the line on the failure of the phonic wheel at either end of the line to exactly synchronise with that at the other.

Phonograph.—An apparatus for the reproduction of articulate speech, or of sounds of any character, at any indefinite time after their occurrence and for any number of times.

In Edison's phonograph the voice of the speaker, received by an elastic diaphragm of thin sheet iron, or other similar material, is caused to indent a sheet of tin-foil placed on the surface of a cylinder C, Fig. 299, that is maintained at a uniform rate of rotation by the crank at W. In the form shown, the motion is by hand, In a later improved form the cylinder is driven by means of an electric motor, or by clockwork.

In order to reproduce the speech or other sounds the *phonogram record* is placed on the surface of a cylinder similar to that on which it was received, (or is kept on the same surface), and the tracing point, placed at the beginning of the record and being maintained against it by gentle pressure, is caused, by the rotation of cylinder, to follow the indentations of the phonogram record. As the point is thus moved up and down the hills and hollows of the record surface, the diaphragm to which it is attached is given a to-and-fro motion that exactly corresponds to the to-and-fro motion it had when impressed originally by the sounds it has recorded on the phonogram record. A person listening at this diaphragm will therefore hear an exact reproduction of the sounds originally uttered.

In this manner, the voices of relatives, distinguished singers, or statesmen can be preserved for future generations.

In Edison's improved phonograph, the record surface consists of a cylinder of hardened wax. The motion of the cylinder is obtained by means of an electric motor. Two diaphragms are used, one for recording, and one for reproducing. As shown in Fig. 300, the recording diaphragm is in position against the cylinder. The recording diaphragm is made of malleable glass. The reproducing diaphragm is formed of bolting silk covered with a thin layer of shellac.

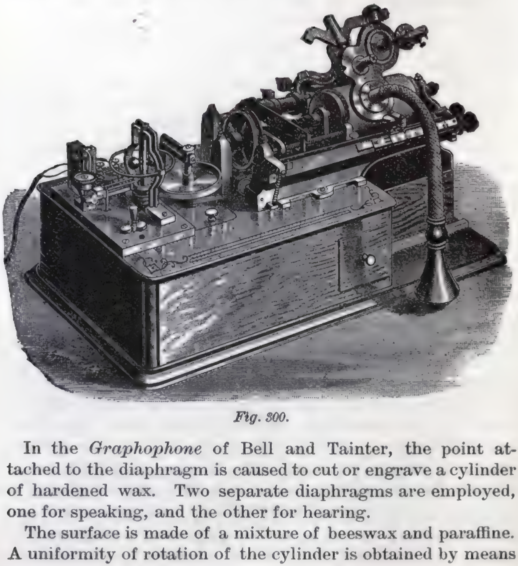


Fig. 300.

In the *Graphophone* of Bell and Tainter, the point attached to the diaphragm is caused to cut or engrave a cylinder of hardened wax. Two separate diaphragms are employed, one for speaking, and the other for hearing.

The surface is made of a mixture of beeswax and paraffine. A uniformity of rotation of the cylinder is obtained by means

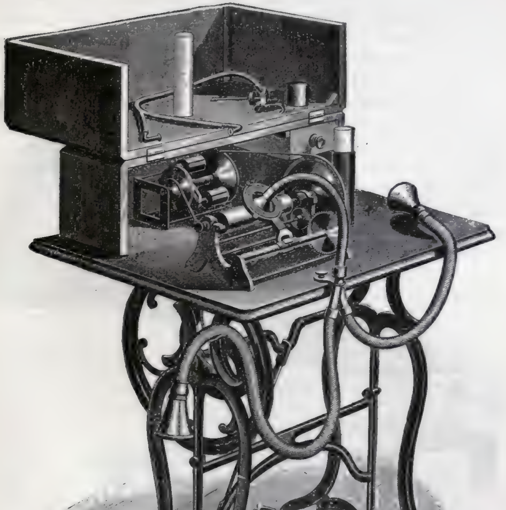


Fig. 301.

of a motor provided with a suitable governor. An ordinary conversation of some five minutes, it is claimed, can be recorded on the surface of a cylinder 6 inches long and $1\frac{1}{4}$ inch in diameter.

In the *Gramophone* of Berliner, a circular plate of metal, covered with a film of finely divided oil or grease, receives the

Fig. 302.

record in a sinuous, spiral line. This record is subsequently etched into the metal by any suitable means, or is photographically reproduced on another sheet of metal.

Glass covered with a deposit of soot is sometimes employed for the latter process. The apparatus is shown in Fig. 302, as arranged for the reproduction of speech.

In Mr. Berliner's apparatus, the record surface is impressed by a point attached to the transmitting diaphragm, *in a direction parallel to the record surface*, and not, as in the instrument

of Mr. Edison, in a direction at right angles to the same. This method, would appear to be the best calculated for the more exact reproduction of articulate speech, since it permits comparatively loud speaking or singing, without interfering with the quality of the reproduced sounds. Since the resistance to indentation, or vertical cutting, increases more rapidly than the increase in the *amplitude of vibration* (See *Amplitude of Vibration*) of the cutting point, it follows that the louder the sounds recorded by the *phonograph* or *graphophone*, the less complete would be the *quality* of the reproduced sounds, or the less the probability of the peculiarities of the speaker's voice being recognized. In order to avoid this, the speaker in the *phonograph* and the *graphophone* speaks in an ordinary conversational tone only.

For purposes of dictation, and most commercial purposes, this is rather an advantage than otherwise.

Phonograph, Graphophone, or Gramophone Records.—Records produced in a phonograph, graphophone, or gramophone, for the subsequent reproduction of audible, articulate speech.

Phonozenograph.—An instrument devised by De Feltre to indicate the direction of a distant sound.

A Deprez-D'Arsonval galvanometer, a Wheatstone's bridge, and a microphone of peculiar construction, are placed in the circuit of a voltaic battery, and a receiving telephone. The observer determines the direction of the distant sound by means of the sounds heard under different conditions in the telephone.

Phontograph.—A name proposed for an electro-thermal recording telephone devised by Irish.

Phosphorescence.—The power of emitting light, or becoming luminous by simple exposure to light.

Bodies that possess the property of phosphorescence, when exposed to a bright light acquire the power of continuing

to emit light, when carried into the dark, for periods varying from a few seconds to several hours. The diamond, barium and calcium sulphides, dry paper, silk, sugar, and compounds of uranium, are examples of phosphorescent substances.

A phosphorescent body generally emits light of the same character as that it absorbed when exposed to the exciting light. That there is an actual absorption, is seen from the fact that the light which has passed through a *fluorescent* solution, fails to produce fluorescent effects in a similar solution. A *selective absorption* has, therefore, been effected.

The effects of phosphorescence appear to be due to *sympathetic vibrations* set up in the molecules of the phosphorescent body by the exciting light. (See *Sympathetic Vibrations.*)

In some cases, however, that are not exactly understood, the wave length of the emitted light is more rapid than that of the exciting light.

The phenomena of *fluorescence* are now generally believed to be due to the phosphorescence of the body during its exposure to the light, The portions traversed by the light are thus temporarily rendered luminous. (See *Fluorescence.*)

The fire-fly, the glow-worm, and decaying animal or vegetable matter, exhibit a species of *phosphorescence*, that appears to be due to the actual oxidation, or gradual burning of a peculiar, specific, chemical substance.

Phosphorescence may therefore be divided into two classes, viz.:

(1) *Physical Phosphorescence*, or that produced, by the actual impact of the light, and,

(2) *Chemical Phosphorescence*, or that caused by an actual chemical combination, or the combustion of a specific substance.

Phosphorescent paints for rendering the position of a push button, electric call, match safe, or other similar object visible at night, consist essentially of sulphides of calcium or barium, or of mixtures of the same.

Phosphorescence, Electric ———— —Phosphorescence caused in a substance by the passage of an electric discharge.

The phosphorescent material is placed in an exhausted glass tube, as shown in Fig. 303, and submitted to the action of a series of discharges, as from a Ruhmkorff coil, or Holtz machine. The violet blue light of such discharge is very efficient in producing phosphorescence. Phosphorescence is thus effected by subjecting the phosphorescent material to the molecular bombardment which thus occurs in a high vacuum. (See *Bombardment, Molecular.*)

Photometer.—An apparatus for measuring the intensity of the light emitted by any luminous source.

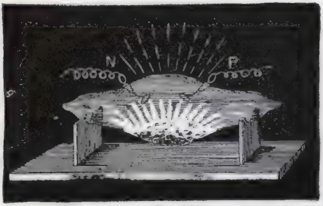


Fig. 303.

There are various methods for measuring the intensity of a beam of light passing through any given space, or emitted from any luminous source; these methods are embraced in the use of the following apparatus:

(1) *Calorimetric Photometer*, in which the light to be measured is absorbed by the face of a thermo-electric pile and the electric current thereby produced is carefully measured. Since *obscure radiation*, or heat will also thus produce an electric current, it is necessary to first absorb all the heat by passing the beam of light through an alum cell.

(2) *Actinic*, or *Chemical Photometers*, in which the intensity of the light is estimated by a comparison of the depth of oloration produced on a fillet of photographic paper under

similar conditions of exposure to a standard light, and the light to be measured.

The combination of pure hydrogen and chlorine, or the decomposition of pure mercurous chloride, have been employed for the purpose of determining the intensities of two lights by measuring the amount of chemical decomposition effected.

(3) *Shadow Photometers*, in which a shadow produced by the light to be measured is compared with a shadow produced by a *standard candle*. (See *Candle, Standard.*)

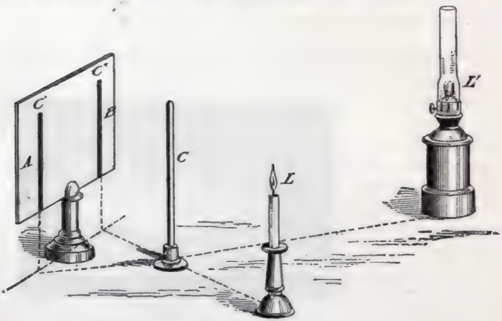


Fig. 304.

Rumford's photometer, shown in Fig. 304, is an example of this form of instrument. The standard candle, shown at L, casts a shadow C″, of an opaque rod C, on the screen at B.

The light to be measured L′, is moved away from the screen until its shadow C′, on the screen at A, is judged by the eye to be of the same depth. The distance between the screen and the lights is then measured in straight lines. *The relative intensities of the two lights are then proportional to the squares of their distances.* If, for example, the candle be at 10 inches

from the screen, and the lamp at 40 inches, then the intensities are as $10^2 : 40^2$ or as $100 : 1600$, or the lamp is a 16 candle-power lamp.

This photometer is based on the fact that the shadow of each source is illumined by the light of the other source.

(4) *Translucent Disc Photometers.*—The light to be measured and a standard candle are placed on opposite sides of a sheet of paper the centre of which contains a grease spot. The standard candle is kept at a fixed distance from the paper and the other light is moved towards or from the paper until both sides of the paper are judged to be equally illumined.

In Bunsen's photometer a vertical sheet of paper with a grease spot at its centre, is exposed to the illumination of a standard candle on one side, and the light to be measured on the other.

The sheet of paper is placed inside a dark box provided with two plane mirrors placed at such an angle to the paper that an observer can readily see both sides of the paper at the same time.

This box can be slid along a graduated, horizontal scale, towards, or from, the light to be measured, and carries with it the standard candle mounted on it at a constant distance of 10 inches. If the box is too near the light to be measured, the grease spot appears brighter on the side of the sheet of paper nearest the candle. If too near the candle, it appears brighter on the side of the sheet of paper nearest the light to be measured. The position in which the spot appears equally bright on both sides, is the position in which it is equally illumined, and the relative intensities of the two lights are then directly as the squares of their distances from the sheet of paper.

Shadow, and translucent disc, photometers being dependent on equal illumination, are reliable only when the color of the lights compared is the same. For the determination of the

photometric intensity of very bright lights, the standard candle is replaced by a *carcel lamp*, a *standard gas jet*, or by the light emitted by a given mass of platinum, heated by a given current of electricity. (See *Carcel Lamp. Carcel Standard Gas Jet. Platinum Standard Light.*)

Preece's photometer belongs to the class of translucent disc photometers. A tiny incandescent lamp is placed in a box, the top of which has a white paper screen on which is a grease spot. The box is placed in the street where the intensity of illumination is to be measured, and the intensity of the light of the incandescent lamp is varied until the grease spot disappears. The current of electricity then passing through the incandescent lamp acts as the measure of the illumination.

In the case of the shadow photometer, or of Bunsen's photometer, if the intensity of illumination is the same, the relative intensities of the two lights may be determined as follows:

Calling I, and i, respectively the relative intensities of the standard light, and the light to be measured, and D, and d, their respective distances from the screen, then

$$I : i :: D^2 : d^2, \text{ or } I \times d^2 = i \times D^2;$$

$$\text{that is, } i = I\left(\frac{d^2}{D^2}\right).$$

Or, the intensity of the light to be measured is $\left(\frac{d^2}{D^2}\right)$ times the intensity of the standard light.

If for example D, and d, represent 10 and 100 inches, respectively, the intensity of i is 100 times the intensity I, the standard light.

(5) *Dispersion Photometers.*—A class of photometers in which, in order to more readily compare or measure a very bright or intense light, like that of an arc lamp, the intensity of the light is decreased by dispersion by a readily measurable amount.

Ayrton & Perry's Dispersion Photometer.—A photometer in which, in order to bring an intensely bright light, like

an electric arc light, to such an intensity as will permit it to be readily compared with a standard candle, its intensity is weakened by its passage through a diverging (concave) lens.

Ayrton & Perry's dispersion photometer is shown in two different positions, Figs. 305 and 306. The apparatus is supported on a tripod stand E, arranged so as to obtain exact levelling. A plane mirror H, movable around a pin placed directly under its centre, can be rotated and thus reflect the light after its passage through the diverging lens, while still maintaining its distance from the electric light.

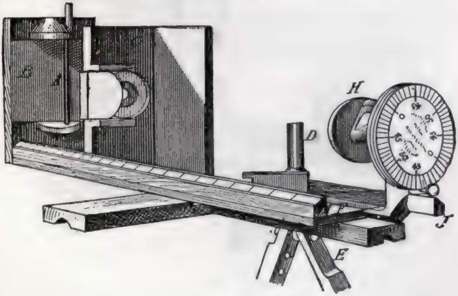


Fig. 305.

The horizontal axis of this mirror is inclined 45° to its reflecting surface in order to avoid errors arising from varying absorption at different angles of reflection.

The inclination of the beam to the horizontal is indicated by means of an index attached to the mirror and moving over the graduated circle G.

A black rod A, casts its shadow on a screen of white blotting paper B. A standard candle, placed in the holder D,

casts its shadow alongside the shadow cast by the electric light. The lens is now displaced until the shadow of the electric light is of the same intensity as that of the candle, when viewed successively through sheets of red and green glass.

A graduated scale serves to mark the distance of the candle and of the lens from the screen, from which data the intensity of the electric light may be calculated.

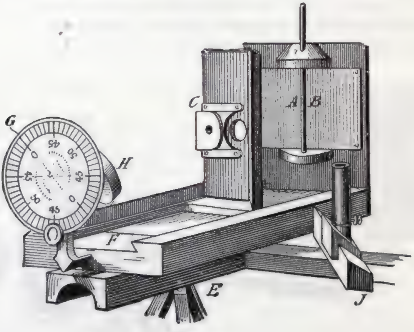


Fig. 306.

(6) *Selenium Photometers.*—Instruments in which the relative intensities of two lights are determined by the effects produced on a selenium resistance.

In Siemens' selenium photometer a selenium cell is employed in connection with an electric circuit for determining the intensity of light.

The tube A B, Fig. 307, is furnished at A with a diaphragm, and at B with a selenium plate, connected by wires, G G, with the circuit of a battery and a galvanometer.

A graduated scale L M, bears the standard candle N.

The tube A B is capable of rotation on the vertical axis F. A reflecting mirror-galvanometer is used in connection with the selenium photometer. The light to be measured is placed at right angles to the scale L M, and the tube A B directed towards it, and the galvanometer deflection compared with the deflection obtained when turned towards the standard candle.

(7) *Gas-Jet Photometers.*—Instruments in which the candle power of a gas jet is determined by measuring the height at which the jet burns when under unit conditions of volume and pressure.

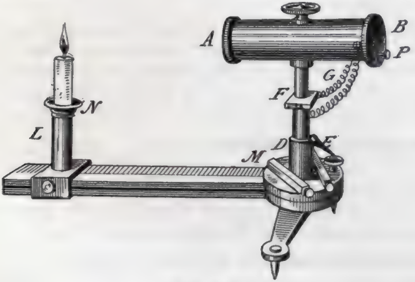


Fig. 307.

In determining the candle power of an intense light like the electric arc light, a large gas light is used intsead of a standard candle, and the photometric power of this gas light is carefully determined by comparison with a gas-jet photometer. (See *Carcel, Standard, Gas Jet.*)

Photophone.—An instrument invented by Bell for the telephonic transmission of articulate speech along a ray of light instead of along a conducting wire.

A beam of light, reflected from a diaphragm against which

the speaker's voice is directed, is caused to fall on a *Selenium resistance* inserted in the circuit of a voltaic battery, and a telephone. The changes thus effected in the resistance of the circuit by the varying amounts of light reflected on the selenium from the moving diaphragm, produce in the receiving telephone, a series of to-and-fro movements, similar to those impressed on the transmitting diaphragm. One listening at the telephone can hear whatever has been spoken at the transmitting diaphragm. Telephonic communication can therefore by such means be carried on along a ray or beam of light, theoretically through any distance. (See *Selenium, Resistance.*)

A block of vulcanite and many other substances may be used as the receiver, since it has been discovered that a rapid succession of flashes of light produces an audible sound in small masses of these substances. The term *Sonorescence* has been proposed for such a property. (See *Sonorescence.*)

Photophore, Trouvé's ——— —An apparatus in which the light of a small incandescent electric lamp is employed for purposes of medical exploration.

A small incandescent lamp is placed in a tube containing a concave mirror and a converging lens.

Phototelegraphy, or Telephotography.—The electric production of pictures, writing, charts, or diagrams at a distance. (See *Telephotography.*)

Photo-Voltaic Effect.—The change in the resistance of selenium or other substances effected by their exposure to light. (See *Selenium Cell.*)

Physiology, Electro ——— —(Sec *Electro-Physiology.*)

Piano, Electric ——— —A piano in which the strings are struck by hammers actuated by means of electro-magnets, instead of by the usual mechanical action of levers.

Electric piano-action is mainly useful in permitting the instrument to be played at any distance from the performer. It is also of value from the ease it affords in recording the piece played.

It fails, however, to properly preserve the various modulations of force so requisite for brilliant instrumentation.

Pickle.—An acid solution in which metallic objects are dipped before being galvanized, or electroplated, in order to thoroughly cleanse their surfaces.

The pickle used for the preparation of iron for galvanization is a weak solution of sulphuric acid in water. Various acids, or acid liquids, are employed for that thorough cleansing of metallic surfaces so necessary in order to ensure an even, uniform, adherent coating of metal by the process of electro-plating. (See *Electro-Plating.*)

Pile, Dry ———— —A voltaic battery, consisting of numerous voltaic couples formed of discs of paper covered on one side with zinc-foil, and on the other with black oxide of manganese. (See *Dry Pile.*)

Pile, Matteucci's Muscular ——— —(See *Muscular Pile, Matteucci's.*)

Pile, Thermo-Electric ——— —A battery consisting of a number of *thermo-electric couples* connected so as to form a single electric source. (See *Thermo-Electric Battery.*)

Pile, Voltaic ———— —A battery consisting of a number of voltaic couples connected so as to form a single electric source.

A form similar to Volta's original pile, consisting of alternate discs of copper and zinc, separated from each other by discs of wet cloth, and piled on one another, so as to form a number of separate voltaic couples connected in series, is shown in Fig. 308. The thick plates marked *Zn*, are of zinc; the copper plates, marked *Cu* are much thinner. The discs of moistened cloth are shown at *d d*. One end of such a

pile, would then be terminated by a plate of copper, and the other by a plate of zinc. The copper end forms the *positive electrode*, and the zinc end the *negative electrode*. (See *Cell, Voltatic, Polarity of Electrodes.*)

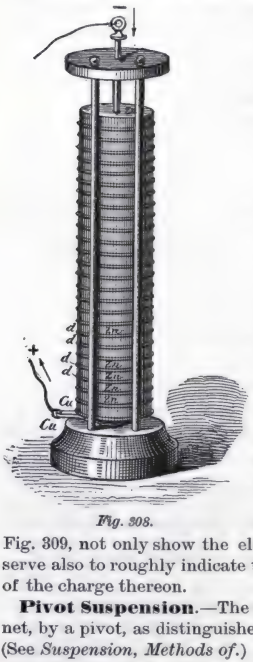


Fig. 308.

Pith.—A light, cellular material forming the central portions of most exogenous plants.

An excellent pith, suitable for electrical purposes, is furnished by the dried wood of the elderberry.

Pith-Ball Electroscope.—An electroscope which shows the presence of a charge by the repulsion of two similarly charged pith balls. (See *Electroscope.*)

Any two pith balls, suspended by conducting threads, but insulated from the earth, will serve as an electroscope.

Pith Balls.—Two balls of pith, suspended by conducting threads of cotton to insulated conductors, and employed to show the electrification of the same, by their mutual repulsion.

The pith balls connected with the insulated cylinder A B, Fig. 309, not only show the electrification of the cylinder, but serve also to roughly indicate the peculiarities of distribution of the charge thereon.

Pivot Suspension.—The suspension of a needle or magnet, by a pivot, as distinguished from suspension by a thread. (See *Suspension, Methods of.*)

Plants, Electricity of ——— —Electricity produced naturally by plants during their vigorous growth.

DuBois-Reymond and others, have shown that plants while in a vigorous vital state, are active sources of electricity. If one of the terminals of a galvanometer be inserted into a fruit near its stem, and the other terminal into the opposite part of the fruit, the galvanometer at once shows the presence of an electric current.

Buff has shown that the roots and interior portions of plants are always negatively charged, while the flowers, fruits and green twigs are positively charged.

Plant tissue or fibre, like the muscular fibre of animals, exhibits in many cases a true contraction on the passage through it of an electric current. This is seen in the *mimosa sensitiva,* or sensitive fern; in the Venus' fly trap; and in several other species of plants.

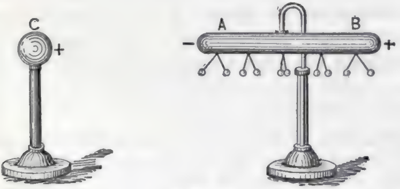


Fig. 309.

Plate Condenser.—(See *Condenser or Accumulator.*)

Plating Bath, Electro ——— —(See *Bath, Electro-Plating.*)

Plating, Electro ———— —The depositing of a plating or coating of one metal on the surface of another metal, or on any conducting surface, by the action of electricity.—(See *Electro-Plating.*)

Platinoid.—An alloy consisting of German silver with one or two per cent. of metallic tungsten.

This alloy is suitable for use in *resistance coils* on account of the comparatively small influence produced on its electric resistance by changes of temperature. (See *Coils, Resistance*),

Its resistance is 60 per cent. higher than that of German silver.

Platinum.—A refractory and not readily oxidizable metal, of a tin white color.

The coefficient of expansion of platinum by heat is nearly that of ordinary glass. Platinum is, therefore, much employed for the leading-in conductors of an incandescent lamp.

Platinum Black.—Finely divided platinum that possesses, in a marked degree, the power of absorbing or occluding gases.

Platinum black is obtained by the action of potassium hydrate on platinum chloride. Unlike metallic platinum it is of a black color.

Platinum-Silver Alloy.—An alloy used for resistance coils, consisting of one part of platinum and two parts of silver.

Platinum Standard Light.—The light emitted by a surface of platinum, one square centimetre in area, at its temperature of fusion.

Plow.—The sliding contacts connected to the motor of an electric street car, and placed within the slotted underground conduit, and provided for the purpose of taking off the current from the electric mains placed therein, as the contacts are pushed forwards over them by the motion of the car.

Similar contacts, placed in the rear of the motor car and drawn after the train, form what is technically known as the *sled*, or when rolling on overhead wires as *trolleys*. (See *Railways, Electric.*)

Plow, Electric —— —A plow driven by an electric motor placed either on a wagon to which the plow is attached,

or by a stationary electro motor, by the aid of cords or other flexible belts.

One of the first practical applications of the electric transmission of energy was for the operation of a plow, driven electrically, by an electric current generated at some distance, and transmitted to the field by suitable conductors.

Plücker Tubes.—(See *Tubes, Plücker.*)

Plug, Infinity ——— —(See *Infinity Plug.*)

Plumbago.—An allotropic modification of carbon.

Plumbago, the material commonly known as *black lead,* is the same as graphite. Powdered plumbago is employed in *electrotyping processes* for rendering non-conducting surfaces electrically conducting. For this purpose powdered plumbago is dusted on the surfaces which thus acquire the power of receiving a metallic lustre by friction. Stove polishes are formed of mixtures of plumbago and other cheaper materials. (See *Graphite.*)

Strictly speaking the term graphite is properly applied to such varieties of plumbago as are suitable for direct use for writing purposes as in lead pencils.

Plunge Battery.—(See *Battery, Plunge.*)

Pneumatic Perforator.—(See *Perforator, Pneumatic.*)

Pneumatic Signals, Electro ————— —(See *Signals, Electro-Pneumatic.*)

Poggendorff's Voltaic Cell.—(See *Cell, Voltaic.*)

Points, Electric Action of ——— —The effect of points placed on an insulated, charged conductor, is to slowly discharge the conductor by *electric convection.* (See *Convection, Electric.*)

The cause of this action is the increased density of a charge on the surface of a conductor in the neighborhood of points. (See *Charge, Distribution of.*)

Points or Rhumbs, of Compass.—The thirty-two points into which a compass card is divided.

Sixteen of these points are shown in Fig. 310. The position of the remaining will be readily seen by an inspection of the figures.

These points are as follows :

1. *North.*
2. N. by E.
3. N. N. E.
4. N. E. by N.
5. N. E.
6. N. E. by E.
7. E. N. E.
8. E. by N.
9. *East.*
10. E. by S.
11. E. S. E.
12. S. E. by E.
13. S. E.
14. S. E. by S.
15. S. S. E.
16. S. by E.
17. *South.*
18. S. by W.
19. S. S. W.
20. S. W. by S.
21. S. W.
22. S. W. W.
23. W. S. W.
24. W. by S.
25. *West.*
26. W. by N.
27. W. N. W.
28. N. W. by W.
29. N. W.
30. N. W. by N.
31. N. N. W.
32. N. by W.

Boxing the Compass, consists in naming all these points consecutively from any one of them.

The direction in which the ship is sailing is determined by means of a point fixed on the inside of the compass box, directly in the line of the vessel's bow.

Points on Lightning Rod.—Points of inoxidizable material, placed on lightning rods, to effect the quiet discharge of a cloud by *convection streams.* (See *Lightning Rods. Convection, Electric.*)

Polarity, Diamagnetic ——— —A polarity, the reverse of ordinary magnetic polarity, assumed by Faraday to explain the phenomena of diamagnetism. (See *Diamagnetism.*)

Faraday assumed that diamagnetic substances, when brought into a magnetic field, such, for example, as north, acquired *north magnetism* in those parts that were nearest the north pole, instead of *south magnetism* as with ordinary magnetic substances. The north pole thus obtained, would, he thought, explain the apparent repulsion of a slender rod of any diamagnetic material, delicately suspended in a strong magnetic field, and cause it to point equatorially, or with the lines of force passing through its least dimensions. This supposition was subsequently abandoned by Faraday. It has recently been revived by Tyndall. (See *Diamagnetic.*)

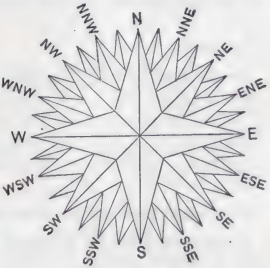


Fig. 310.

Polarity, Magnetic ——— —The polarity acquired by a magnetizable substance when brought into a magnetic field.

The direction of magnetic polarity, acquired by a substance when brought into a magnetic field, depends on the direction in which the lines of magnetic force pass through it. Where these lines enter the substance a south pole is produced, and where they pass out, a north pole is produced. The *axis of magnetization lies in the direction of the lines of force as they pass through the body,* and the *intensity of magnetization,* depends on the number of these lines of force.

The cause of magnetic polarity is not definitely known. Hughes's hypothesis attributes it to a property inherent in all matter. Ampère attributes it to closed electric circuits in the ultimate particles. Whatever its cause, it is invariably manifested by a magnetic field, the lines of force of which are assumed to have the direction already mentioned.

Polarization of Dielectric.—A molecular strain produced in the dielectric of a Leyden jar, by the attraction of the electricities on its opposite faces, or by electrostatic stress. (See *Dielectric Strain.*)

The polarization of the glass of a Leyden jar, and the accompanying strain, are seen by the frequent piercing of the glass, and by the *residual charge* of the jar. (See *Charge, Residual.*)

Polarization of Electrolyte.—The formation of molecular groups or chains, in which the poles of all the molecules of any chain are turned in the same direction, viz., with their positive poles facing the negative plate, and their negative poles facing the positive plate. (See *Cell, Voltaic. Grothüss' Hypothesis.*)

Polarization of Nerves.—(See *Electrotonus.*)

Polarization of Voltaic Cell.—The collection of a gas, generally hydrogen, on the surface of the negative element of a voltaic cell.

The collection of a positive substance like hydrogen on the negative element or plate of a voltaic cell, sets up a *counter electromotive force,* which tends to produce a current in the opposite direction to that produced by the cell, and thus to decrease the normal current of the cell. (See *Counter Electromotive Force.*)

The causes of the decrease of the normal current of a voltaic cell by its polarization, are as follows :

(1) The *Increased Resistance of the cell* owing to the bubbles of gas, which form part of the circuit.

(2) The *Counter Electromotive force,* produced by the film of gas on the negative plate.

There are three ways in which the ill effects of this polarization can be avoided. These are :

(1) *Mechanical.*—The negative plate is furnished with a roughened surface which enables the bubbles of gas to escape

from the points on such surface; or, a stream of gas, or air, is blown through the liquid against the plate to brush the bubbles off.

(2) *Chemical.*—The surface of the negative plate is surrounded by some powerful oxydizing substance, such as chromic or nitric acid, which is capable of oxidizing the hydrogen, and thus thoroughly removing it from the plate. The oxidizing substance may form the entire electrolyte, as is the case of the bichromate solution employed in the zinc-carbon couple. Generally, however, it has been found preferable to employ a separate liquid, like nitric acid to completely surround the negative plate, and another liquid for the positive plate, the two liquids being generally kept from mixing by a porous cell, or diaphragm. Such cells are called *double fluid cells.* (See *Cell, Voltaic, Double Fluid.*)

(3) *Electro Chemical.*—This also necessitates a double fluid cell. The negative element is immersed in a solution of a salt of the same metal as the negative plate. Thus, a copper plate, immersed in a solution of copper sulphate, cannot be polarized since metallic copper is deposited on its surface by the action of the hydrogen which tends to be liberated there. The constancy of action of a Daniell cell depends on a deposition of metallic copper on its copper plate as well as on the formation of hydrogen sulphate, and the solution of additional copper sulphate. (See *Cell, Voltaic, Daniell's.*)

Polarized Armature.—(See *Armature, Polarized.*)

Polarized Relay.—(See *Relay, Polarized.*)

Pole, Antilogous ——— —That pole of a pyro-electric substance, like tourmaline, which acqures a negative electrification when the temperature is rising, and a positive electrification when it is falling, (See *Pyro-Electricity.*)

Pole Changer.—A switch or key for changing or revers-

ing the direction of current produced by any electric source, such as a battery.

The *commutator of a Ruhmkorff coil* is a simple form of pole changer. (See *Induction Coils.*)

Pole Pieces.—Pieces of soft iron placed at the ends of the poles of electro magnets for the purpose of concentrating and directing their magnetic fields.

Pole Pieces of Dynamos.—Masses of iron connected with the poles of the field magnet frames of dynamo-electric machines, and shaped to conform to the outline of contour of the armature.

The pole pieces are made in a variety of forms, but in all cases are so shaped as to conform to the outline of the space in which the armature rotates.

They are brought as near as possible to the armature so as to increase the intensity of the magnetic induction. The intervening air space should be as thin as possible, but of as large an area as convenient.

The opposite pole pieces should not have their extensions brought too near together, as this will permit of serious loss through *magnetic leakage.* The distance between them should be as many times the depth of the armature windings as possible. (See *Magnetic Leakage.*)

Rounded edges are preferable to sharp edges for the same reason.

Poles, Consequent ——— of Magnet.—(See *Consequent Magnet Poles.*)

Poles, False ————(See *False Poles.*)

Poles of Magnetic Intensity.—The earth's magnetic poles as determined by means of the needle of oscillation.

The points of the earth's greatest magnetic intensity. (See *Inclination Chart.*)

Poles of Verticity, Magnetic.—The earth's magnetic poles as determined by means of the dipping needle.

The points of the north where the angle of dip is 90°. (See *Inclination Chart.*)

Poles, Telegraphic ———Wooden or iron uprights on which telegraphic or other wires are hung.

Wooden poles are generally round.

The *terminal pole*, or the last pole at each end of the line, or where the wires bend at an angle of nearly 90°, is generally cut square.

The holes for the poles must be dug in the true line of the wires, and not at an angle to such line. As little ground should be disturbed in the digging as possible. *Earth borers*, or modifications of the ordinary ship auger, are generally employed for this purpose. When the pole is placed in position the ground should be *rammed*, or *punned* around the pole.

In *setting the pole*, it is generally set at least five feet in the ground. In England the poles are planted to a depth of about one-fifth of their length. In embankments and loose ground, they are planted deeper than in more solid earth. On curves, the poles should be inclined a little so as to lean back against the lateral strain of the wire, since by the time the ground has completely set, the strain of the wire will have pulled them into an erect position.

Care must be taken to so plant the poles on that side of a road or railway, that the prevailing winds will blow them off the same, should it overturn them. As to location, the top of steep cuttings is preferable to the slope. In all exposed positions, it is preferable to strengthen the poles by *stays* attached to both sides.

Where the number of wires is unusually large, heavy timber, or in case of its absence, double poles suitably braced together, must be employed. In long lines the poles should all be numbered in order to afford ease for reference or repair.

When, even with the best *punning*, and other precautions, the pole is judged to be unable to resist the strain on it, *stays*

and *struts* are employed. A *stay* is used when it is desired to remove the *pull* or *tension* from the pole; a *strut*, when it is desired to remove the *thrust* or *pressure*.

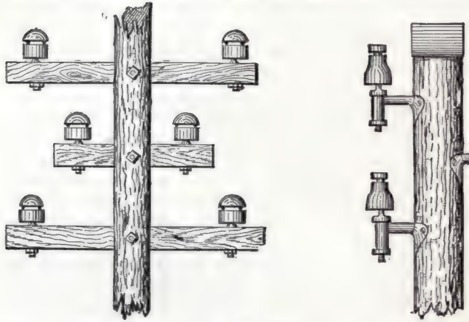


Fig. 311.

The *arms* or *brackets*, or the cross pieces that support the *insulators*, should all be placed on the same side of the poles. Some common forms of arms or brackets are shown in Fig. 311.

Saddle Brackets should be placed on alternate sides of the pole. When the strain on an insulator is too great, on account of the wire going off at a sharp angle, a *Shackle* is used. This is a special form of insulator which confines the strain to one spot.

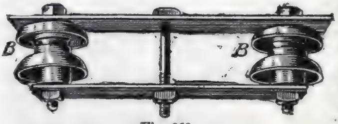


Fig. 312.

A form of *Double Shackle* is shown in Fig. 312. The wire passes around the recess at B, between the two insulators.

On curves, or in any situation when there is a probability, in

case of the breaking of an insulator, of a wire getting into a dangerous position *Guards* should be employed.

Guards are of two kinds, viz.: *Hoop Guards* and *Hook Guards.* A form of *hook guard* is shown in Fig. 313.

When wooden poles are employed various preservative methods are adopted to protect the wood from decay, which is very apt to occur, especially at the line of the pole enters the ground. Some of these forms are as follows, viz.:

(1) *Charring* and *Tarring* the butt end of the pole where it enters the ground, so as to expel the sap and destroy injurious plants or animal germs.

The charred end is then cleansed and dipped in a mixture of tar and slaked lime.

(2) *Burnetising,* or the introduction of chloride of zinc into the pores of the wood, by placing the poles in an open tank filled with a solution of this salt.

(3) *Kyanising,* or the similar introduction of corrosive sublimate, or mercuric chloride.

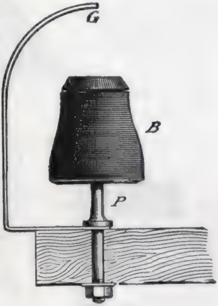


Fig. 313.

(4) *Boucherising,* or the injection of a solution of copper sulphate, into the pores of the wood.

(5) *Creosoting,* or the application of creosote to well-seasoned poles.

Porous Cells.—Jars of unglazed earthenware, employed in double-fluid voltaic cells, to keep the two liquids separated.

The use of a porous cell necessarily increases the internal resistance of the cell, from the decrease it produces in the area of cross section of liquid between the two elements. When the battery is dismantled, the porous cells should be kept under water, otherwise the crystallization of the zinc sulphate or

other salt is apt to produce serious exfoliation, or even to crumble the porous cell.

A porous cell is sometimes called a *diaphragm.* (See *Cell, Voltaic.*)

Portative Power.—The lifting power of a magnet. (See *Lifting Power of Magnet.*)

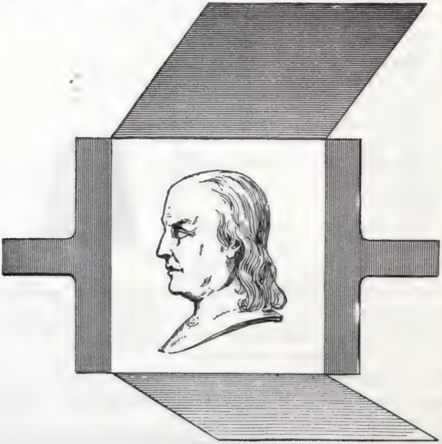


Fig. 314.

Portrait, Electric———A portrait formed on paper by the electric volatilization of gold or other metal.

An electric portrait, is obtained by cutting on a thin card a portrait, in the form of a stencil. A sheet of gold leaf is then placed on one side of the paper stencil, and a sheet of paper on the other side; sheets of tin foil are then placed on the outside, as shown in Fig. 314, and the whole firm'y p"essed

together. If now a disruptive discharge is passed through from one sheet of tin foil to the other, the gold leaf is volatilized, and a purplish stain is left on the paper on the outlines of the stencilled card, thus forming an electric portrait.

Positive Electricity.—One of the phases of electrical excitement, rather than one of the kinds of electricity. (See *Negative Electricity.*)

Positive Direction of Lines of Magnetic Force.—The direction the lines of magnetic force are assumed to take, viz.: *out of the north pole of a magnet and into the south pole.* (See *Field, Magnetic. Direction of Lines of Force.*)

Posts, Binding —— or Binding Screws.—(See *Binding Posts.*)

Potential, Constant ——.—A potential which remains constant under all conditions.

A machine or other electric source is said to have a constant potential when it is capable, while in operation, of maintaining a constant difference of electric pressure between its two terminals. (See *Circuit, Constant Potential.*)

Potential, Difference of —— ——.—(See *Difference of Potential.*)

Potential, Difference of —— Methods of Measuring —— —— ——.—Methods employed for determining difference of potential.

These methods are as follows:

(1) *By the Method of Weighing*, that is, by obtaining the *weight* required to overcome the attraction between two oppositely charged plates, or oppositely energized coils; or by measuring the repulsion between similarly charged surfaces, or similarly energized coils.

(2) *By the use of Electrometers,* or apparatus designed for measuring differences of potential. (See *Electrometers.*)

(3) *By the use of Galvanometers.*

Difference of potential, in the case of currents, may be determined from the quantity of electricity which flows per second through a given circuit, that is, by the number of ampères, just as the pressure of water at any point in the side of a containing vessel can be determined by the quantity of water that flows per second. Difference of potential in the case of currents, therefore, may be measured by any galvanometer which measures the current directly in ampères, and knowing the resistance of the circuit.

Potential, Electric ———— —The power of doing electric work.

Electric level.

Electric potential can be best understood by comparison with the case of a liquid such as water.

The ability of a water supply or source to do work depends:

(1) On the Quantity of Water.

(2) On the Level of the Water, as compared with some other level, or, in other words on the *difference between the two levels.*

In a like manner the ability of electricity to do work depends :

(1) On the Quantity of Electricity.

(2) On the Electric Potential at the place where the elecricity is produced, as compared with that at some other place, r, in other words on *the Difference of Potential.*

In the case of water flowing through a pipe, the quantity which passes in a given time is the same at any cross section of the pipe.

In the case of electricity, the quantity of electricity flowing through any conductor, or part of a circuit, is the same at any cross section. A galvanometer introduced into a break in any part of the conductor would show the same strength of current.

But, though the quantity of water which passes is the same at any cross section of a pipe, the *pressure per square inch* is

not the same, even in the case of a horizontal pipe of the same diameter throughout, but becomes less, or suffers a *loss of head*, or *difference of pressure*, at any two points along the pipe, that causes the flow between these two points against the *resistance of the pipe.*

So too, in the case of a conductor carrying an electric current, though the quantity of electricity that passes is the same at all cross sections, the *electric pressure* or *potential* is by no means the same at all points in the conductor, but suffers a *loss of electric head* or *level* in the direction in which the electricity is flowing. It is this loss of electric head or level, or *difference of electric potential*, that causes the electricity to flow against the *resistance of the conductor.*

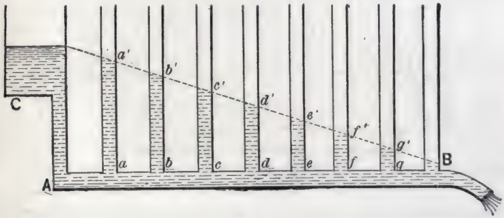


Fig. 315.

These analogies can be best shown by the following illustration :

In Fig. 315, a reservoir, or source of water, at C, communicates with the horizontal pipe A B, furnished with open vertical tubes at *a*, *b*, *c*, *d*, *e*, *f*, *g*, and B. If the outlet at B is closed, the level of the water in the communicating vessels is the same as at the source ; but if the liquid escape freely from B, the level of the water in the branch pipes, will be found on the inclined dotted line or at *a′*, *b′*, *c′*, *d′*, *e′*, *f′*, *g′*, or on the *hydraulic gradient.*

The pressure per square inch, at any cross section of the horizontal pipe, which is measured by the height of the liquid in the vertical pipe at that point, *decreases in the direction in which the liquid is flowing.* The force that urges the liquid through the pipe between any two points, may be called the *liquid-motive force* (*Fleming*) and is measured by the *difference of pressure* between these points.

In Fig. 316, the dynamo electric machine at D, has its negative pole grounded, and its positive pole connected to a long lead, A B, the postive end of which is also grounded. *A fall of potential,* represented by the inclined dotted line, occurs between A and B, *in the direction in which the electricity is flowing.*

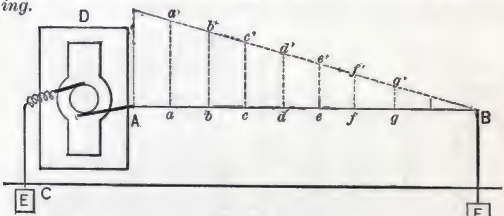


Fig. 316.

The dynamo electric machine may be regarded as a pump that is raising the electricity from a lower to a higher level, and passing it through the lead A B. The electric *pressure* or *potential* producing the flow is greatest near the dynamo and least at the further end, the differences at the points *a*, *b*, *c*, *d*, *e*, *f*, and *g*, being represented by the vertical lines *a a'*, *b b'*, *c c'*, *d d'*, *e e'*, *f f'*, and *g g'*.

The electricity flows between any two points as *a*, and *b*, in the conductor A B, in virtue of the difference of electric pressure or potential between these two parts, or the difference between *a a'*, and *b b'*.

Differences of potential must be distinguished from differ-

ences in electric charge, or *electrostatic density.* If two conductors at different potentials are connected by a conductor, a current will flow through this conductor. When their potential is the same *no current flows.* The density of a charge is the quantity of electricity per unit of area.

The electric potential is the same at all points of an insulated charged conductor; the density is different at different points, except in the case of a sphere. The potential, however, is the same, since no current flows, or the charge does not redistribute itself. The density on an insulated, isolated sphere is uniform over all parts of the surface, and its potential is the same at all points. If now the sphere be approached to another body, its density will vary at different parts of its surface, and while the charge is redistributing itself so as to produce these differences in density the potential will vary. As soon, however, as this redistribution is effected and no further current exists, the potential is the same over all parts, though the density differs at different points.

Potential, Electrostatic ———.—The power of doing work possessed by a unit quantity of positive electricity charged on an insulated body.

The electric potential of any point may also be defined as being equal to the work required to be exerted on a unit of positive electricity in bringing it to that point from zero potential, *i. e.*, from an infinite distance.

Potential Energy.—Energy possessing the power or potency of doing work, but not actually performing such work. (See *Energy, Potential.*)

Potential, Fall of ———.—(See *Potential, Electric.*)

Potential, Magnetic ———.—The amount of work required to bring up a unit north-seeking magnetic pole from an infinite distance to another unit north-seeking magnetic pole.

Potential of Conductor, Methods of Varying

———— —The potential of a conductor may be varied in the following ways:

(1) By varying its electric charge.

(2) By varying its shape without altering its charge.

(3) By varying its position as regards neighboring bodies.

This resembles the case of a gas whose tension or pressure may be varied as follows, viz.:

(1) By varying the quantity of gas.

(2) By varying the size of the gas holder in which it is kept, and,

(3) By varying the temperature.

Difference of potential, therefore corresponds,

(1) With difference of level in liquids.

(2) With difference of pressure in gases.

(3) With difference of temperature in heat. (*Ayrton.*)

Potential, Zero ——— —An arbitrary level from which electric potentials are measured.

As we measure the heights of mountains from the arbitrary mean level of the sea so we measure electric levels from the arbitrary level of the potential of the earth.

The true zero potential would be situated at a point infinitely distant from any electrified body.

Potentiometer.—An apparatus for the galvanometric measurement of electro-motive forces, or differences of potential by a zero method. (See *Null*, or *Zero Methods.*)

In the potentiometer the difference of potential to be measured is balanced, or opposed, by a known difference of potential, and the equality of the balance is determined by the failure of one or more galvanometers, placed in shunt circuits, to show any movement of their needles.

The principle of operation of the potentiometer will be understood from an inspection of Fig. 317. A secondary battery S, has its terminals connected to the ends of a uniform wire A B, of high resistance called the *Potentiometer Wire.* There will therefore occur a regular drop or fall of

potential along this wire, which, since the wire is uniform, will be equal per unit of length. This drop of potential can be shown by connecting the terminals of a delicate high resistance galvanometer to different parts of the wire, when the deflection of the needle will be proportional to the drop of potential between the two points of the wire touched. If now the terminals of a *Standard Cell* be inserted in the circuit of the galvanometer, so as to oppose the current taken from the potentiometer wire, and the contacts of the potentiometer wire be slid along it until no deflection of the galvanometer needle is produced, the drop of potential between these two points on the potentiometer wire will be equal to the difference of potential of the standard cell. (See *Standard Cell.*)

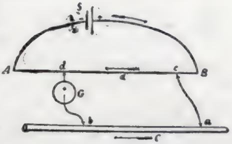


Fig. 317.

Suppose now it be desired to measure the difference of potential between two points *a* and *b*, on the wire C, through which a current is flowing. Connect the points *b* and *d*, and *a* and *c*, as shown, with the delicate high resistance galvanometer G, in either of them. Now slide *c* towards *d*, until the needle of G shows no deflection. The potential between *a* and *b*, is then equal to that between *c* and *d*.

Potentiometer Wire.—The wire of a potentiometer which has been calibrated for its drop of potential. (See *Potentiometer.*)

Power.—Rate of doing work.

Mechanical power is generally measured in *horse power*, which is equal to work done at the rate of 550 *foot-pounds per second.*

The C. G. S. Unit of Power is one Erg per Second.

The practical unit of power is the Watt, or 10,000,000 ergs per second.

$$1 \text{ Watt} = \tfrac{1}{746} \text{ H. P.}$$

Power, Absorptive ——— —(See *Absorptive Power.*)

Power, Stray ——— —(See *Stray Power.*)

Power, Thermo-Electric ——— —A number which, when multiplied by the difference of temperature of a thermo-electric couple, will give the difference of potential thereby generated in micro-volts. (See *Diagram, Thermo-Electric.*)

Power, Units of ——— —Various units designed for the measurement of power.

The following table of Units of Work, and of Power is taken from Hering's work on Dynamo Electric Machines :

Work

1 erg	= 1. dyne-centimetre.
1 "	= .0000001 joule.
1 gram-centimetre	= 981.00 ergs.
1 "	= .00001 kilogram-metre.
1 foot-grain	= 1937.5 ergs.
1 joule, or	= 10,000,000 ergs.
1 volt-coulomb, or	= .737324 foot-pound.
1 watt during every second, or	= .101937 kilogram-metre.
1 volt-ampère during every second	= .0013592 metric horse power for one second.
"	= .0013406 horse power for one second.
"	= .0009551 pound-Fah., heat unit.
"	= .0005306 pound-Centig., heat unit.
"	= .0002407 kilogr. - Centig. heat unit.
"	= .0002778 watt-hour.
1 foot-pound	= 13562600 ergs.
"	= 1.35626 joules.

1 foot-pound	= .13825 kilogram-metre.
"	= .0018434 metric horse-power for one second.
"	= .00181818 horse-power for one second.
"	= .0012953 pound-Fah., heat unit.
"	= .0007196 pound - Centig., heat unit.
"	= .0003264 kilogr. - Centig., heat unit.
"	= .0003767 watt-hour.
1 kilogram-metre	= 98100000 ergs.
"	= 9.81000 joules.
"	= 7.23314 foot-pounds.
"	= .01333 metric horse-power for one second.
"	= .013151 horse - power for one second.
"	= .009369 pound-Fah., heat unit.
"	= .005205 pound-Centig., heat unit.
"	= .002361 kilogr.-Centig. heat unit.
"	= .002725 watt-hour.
1 watt-hour	= 3600. joules.
"	= 2654.4 foot-pounds.
"	= 366.97 kilogram-metres.
"	= 3.4383 pound-Fah., heat units.
"	= 1.9102 pound-Centig., heat units.
"	= .8664 kilogr.-Centig., heat units.
"	= .0013592 metric horse - power-hour.
"	= .0013406 horse-power-hour.
1 metric horse-power-hour	= 2648700 joules.
"	= 1952940 foot-pounds.
"	= 270000 kilogram-metres.
"	= 2529.7 pound-Fah., heat units.

1 metric horse-power-hour = 1405.4 pound-Centig., heat units.
" = 637.5 kilogr.-Centig., heat units.
" = 735.75 watt-hours.
" = .98634 horse-power-hour.
1 horse-power-hour ...... = 2685400 joules.
" ...... = 1980000. foot-pounds.
" ...... = 273740 kilogram-metres.
" ...... = 2564.8 pound-Fah., heat units.
" ...... = 1424.9 pound-Centig., heat units.
" ...... = 646.31 kilogr.-Centig., heat units.
" ...... = 745.941 watt-hours.
" ...... = 1.01385 metric horse-power-hour.

Heat.

1 gram-Centigrade ...... = .001 kilogram-Centigrade.
1 pound-Fahrenheit ...... = 1047.03 joules.
" ...... = 772 foot-pounds.
" ...... = 106.731 kilogram-metres.
" ...... = .55556 pound-Centigrade.
" ...... = .25200 kilogram-Centigrade.
" ...... = .29084 watt-hour.
" ...... = .0003953 metric horse-power-hour.
" ...... = .0003899 horse-power-hour.
1 pound-Centigrade ...... = 1884.66 joules.
" ...... = 1389.6 foot-pounds.
" ...... = 192.116 kilogram-metres.
" ...... = 1.8000 pound-Fahrenheit.
" ...... = .4536 kilogram-Centigrade.
" ...... = .52352 watt-hour.
" ...... = .0007115 metric horse-power-hour.
" ...... = .0007018 horse-power-hour.
1 kilogram-Centigrade .... = 4154.95 joules.
" .... = 3063.5 foot-pounds.

1 kilogram-Centigrade....	= 423.54 kilogram-meters.
"	= 3.9683 pound-Fahrenheit.
"	= 2.2046 pound-Centigrade.
"	= 1.1542 watt-hours.
"	= .001569 metric horse-power-hour.
"	= .0015472 horse-power-hour.

Power.

1 erg per second	= .0000001 watt.
1 watt, or...............	= 10000000. ergs per second.
1 volt-ampère, or	= 44.2394 foot-pounds per min.
1 joule per second, or	= 6.11622 kilogram-metres per min.
1 volt-coulomb per second	= .0573048 lb.-Fah., heat unit per min.
"	= .0318360 lb.-Cent., heat unit per min.
"	= .0144402 klgr.-Cent. heat unit per min.
"	= .0013592 metric horse-power.
"	= .0013406 horse-power.
1 foot-pound per min.....	= 226043 ergs per second.
"	= .0226043 watt.
"	= .13825 kilogram-metre per min.
"	= .00003072 metric horse-power.
"	= .000030303 horse-power.
1 kilogram-metre per min	= 1635000. ergs per second.
"	= .163500 watt.
"	= 7.23314 foot-pounds per min.
"	= .0002222 metric horse-power.
"	= .0002192 horse-power.
1 metric horse-power	= 735.75×10^7 ergs per second.
or..................	= 735.750 watts.
1 French horse-power....	= 32549.0 foot-pounds per min.
or..................	= 4500 kilogram-metres per min.

1 cheval-vapeur, or	= 42.162 lb.-Fah., heat units per min.
1 force de cheval, or	= 23.423 lb.-Cent., heat units per min.
1 Pferdekraft	= 10.625 klg.-Cent., heat units per min.
"	= .98634 horse-power heat units per min.
1 horse-power	= 745.94×10^7 ergs per second.
"	= 745.941 watts.
"	= 33000 foot-pounds per min.
"	= 4562.33 kilogram - metres per min.
"	= 42.746 lb.-Fah., heat units per min.
"	= 23.748 lb.-Cent., heat units per min.
"	= 10.772 klg.-Cent., heat units per min.
"	= 1.01385 metric horse-power.
1 lb. Fah., heat unit per min.	= 17.45×10^7 ergs per second.
"	= 17.4505 watts.
"	= .23718 metric horse-power.
"	= .023394 horse-power.
1 lb. Cent., heat unit per min.	= 31.41×10^7 ergs per second.
"	= 31.4109 watts.
"	= .04269 metric horse-power.
"	= .042109 horse-power.
1 klgr.-Cent., heat unit per min.	= 69.25×10^7 ergs per second.
"	= 69.249 watts.
"	= .09412 metric horse-power.
"	= .092835 horse-power.

(*Hering.*)

Practical Units.—(See *Units, Practical.*)

Primary Battery.—(See *Battery, Primary.*)

Prime Conductor.—The positive conductor of a frictional electric, or electrostatic machine. (See *Machine, Electric, Frictional.*)

Prime Motor.—(See *Motor, Prime.*)

Probe, Electric ——— —Metallic conductors, inserted in the body of a patient, to ascertain the exact position of a bullet or other metallic body.

The conductors are placed parallel, and are separated at the extremity of the probe by any suitable insulating material. On contact with the metallic substance, an electric bell is rung by the closing of the circuit, or the same thing is more readily detected by the deflection of the needle of a galvanometer, or by a telephone placed in the circuit.

Process, Electrotype——— —(See *Electrotype Process.*)

Processes of Carbonization.—(See *Carbonization, Processes of.*)

Prony-Brake.—(See *Brake, Prony.*)

Proof-Plane.—A small insulated conductor employed to take test charges from the surface of an insulated, charged conductor.

The proof-plane is used in connection with some forms of electrometer.—(See *Balance, Torsion, Coulomb's.*)

Proof-Plane, Magnetic ——— ——— —A small coil of wire placed in the circuit of a delicate galvanometer, and used for the purpose of exploring a magnetic field.

When the coil is suddenly inverted in a magnetic field, if a long coil galvanometer provided with a heavy needle is used, the number of lines of force which pass through the area of cross section of the coil, will be proportional to the sine of half the angle of the first swing of the needle.

Proportionate Arms of Electric Bridge.—A term applied to two of the arms of an electric bridge or balance. (See *Balance, Whealstone's Electric, Box Form of.*)

Prostration, Electric——— —(See *Sun Stroke, Electric.*)

Protection, Electric ——— of Houses, Ships and Buildings Generally. (See *Lightning Rods.*)

Protection, Electric ——— of Metals.—(See *Metals, Electric Protection of.*)

Protector, Lightning ——— —(See *Lightning Arrester.*)

Protector, Vacuum Lightning ——— —A protector consisting of a glass vessel in which the line wires and an earth wire are fused, and in which a partial vacuum is maintained.

Vacuum protectors are employed on the lines of submarine cables, or underground lines, in order to protect them from lightning discharges.

A discharge of high potential passes more readily through this partial vacuum to the ground than through the line wires.

Protoplasm, Effects of Electric Currents on ——— —Contractions observed in all protoplasm on the passage of an electric current through it.

Protoplasm, the basis of plant and animal life, or the jelly like matter that fills all organic cells, whatever may be the origin of such cells, suffers contraction when traversed by an electric current.

An increased activity of the movements of the *amœba* is occasioned by slight shocks from an induction coil; stronger discharges produce tetanic contractions, with, in some cases, expulsion of food or even of the nucleus. A uniform strength of current produces contraction and imperfect tetanus,

Pump, Mechanical Air—— —A mechanical device for exhausting or removing the air from any vessel.

An excellent form of air pump is shown in Fig. 318, which is a drawing of Bianchi's pump.

Three valves, all opening upwards, are placed at the top and bottom of the cylinder, and in the piston, respectively. These valves are mechanically opened and closed at the proper moment by the movements of the piston, *i. e.*, their action is *automatic*. This enables a much higher vacuum to be obtained than when the valves open and close by the tension of the air.

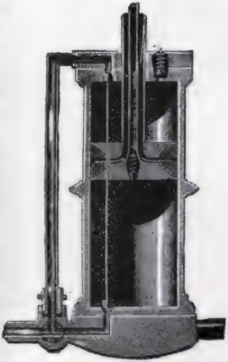


Fig. 318.

Mechanical pumps are unable to readily produce the high vacua employed in most electric lamps. Mercury pumps are employed for this purpose.

Pumps, Mercurial Air—— —Devices for obtaining high vacua by the use of mercury.

Mercury pumps are, in general, of two types of construction, viz.:

(1) The Geissler Pump.

(2) The Sprengel Pump.

In the *Geissler Mercury Pump*, Fig. 319, a vacuum is obtained by means of the Torricellian vacuum produced in a large glass bulb that forms the upper extremity of a *barometric column*. (See *Barometric Column*.) The lower end of this tube or column is connected with a reservoir of mercury by means of a flexible rubber tube. To fill the bulb with mercury the reservoir is raised above its level, *i. e.*, above thirty inches, the air it contains being allowed to escape through an opening governed by a stop-cock. The vessel to be exhausted is

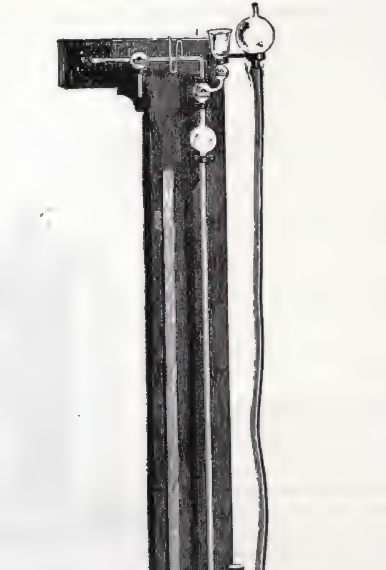


Fig. 319.

connected with the bulb, and by means of a two-way exhaustion cock, communication can be made with the bulb, when it contains a Torricellian vacuum, and shut off from it while its air is being expelled.

In actual practice the mercury is mechanically pumped into the barometric column, and the valves are opened either by hand, or, automatically by suitable mechanism, or by electrical means.

Fig. 320.

In the *Sprengel Mercury Pump,* Fig. 320, a vacuum is obtained by means of the fall of a stream of mercury in a vertical tube of comparatively fine bore, which dips below a mercury level. The fall of a mercury stream causes the exhaustion of a reservoir connected with the vertical tube, by the mechanical action of the mercury in entangling bubbles of air. These bubbles are largest at the beginning of the exhaustion, but become smaller and smaller near the end, until, at last, the characteristic metallic click of mercury or

other liquid falling in a good vacuum is heard. The exhaustion may be considered as completed when the bubbles entirely disappear from the column.

The Sprengel pump produces a better vacuum than the Geissler pump, but is slower in its action.

In actual practice, the mercury that has fallen through the tube is again raised to the reservoir connected to the drop tube by the action of a mechanical pump.

Punning of Telegraph Poles.—Ramming or packing the earth around the base of a telegraph pole for the purpose of more securely fixing it in the ground.

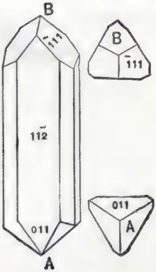


Fig. 321.

Push Button.—(See *Button, Push.*)

Pyro Electricity.—Electricity developed in certain crystalline bodies by heating or cooling them.

Tourmaline possesses this property in a marked degree. When a crystal of tourmaline is heated or cooled, it acquires opposite electrifications at opposite ends or poles.

In the crystal of tourmaline shown in Fig. 321, the end A, called the *analogous pole*, acquires a positive electrification, and the end B, called the *antilogous pole*, a negative electrification, *while the temperature of the crystal is rising.* While cooling the opposite electrifications are produced.

A heated crystal of tourmaline, suspended by a fibre, is attracted or repelled by an electrified body or by a second heated tourmaline, in the same manner as an electrified body.

Many crystalline bodies possess similar properties. Among these are the ore of zinc known as electric calamine or the silicate of zinc, boracite, quartz, tartrate of potash, sulphate of quinine, etc.

Pyromagnetic Motor.—A motor driven by the attraction of magnet poles on a movable core of iron unequally heated.

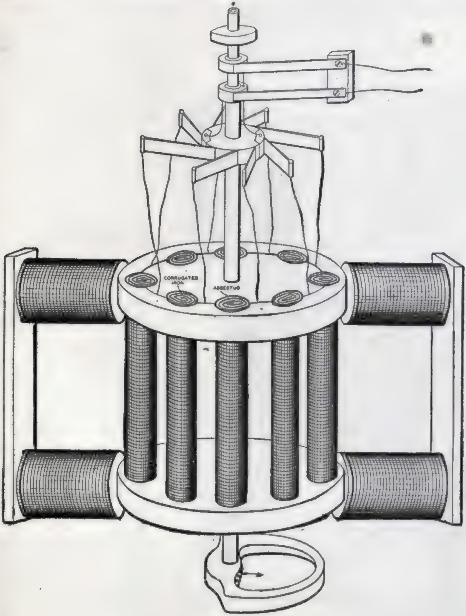


Fig. 322.

The intensity of magnetization of iron decreases with an increase of temperature, iron losing most of its magnetization at

a red heat. A disc of iron, placed between the poles of a magnet so as to be capable of rotation, will rotate if heated at a part nearer one pole than the other, since it becomes less powerfully magnetized at the heated part.

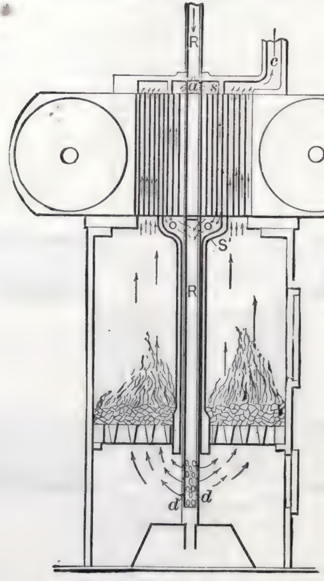


Fig. 323.

In the form of pyromagnetic motor devised by Edison, and shown in Fig. 322, in elevation, and in Fig. 323, in vertical sec-

tion, the disc of iron is replaced by a series of small iron tubes, or divided annular spaces, heated by the products of combustion from a fire placed beneath them. In order to render this heating local, a flat screen is placed dissymetrically across the top to prevent the passage of air through the portion of the iron tubes so screened. The air is supplied to the furnace by passing down from above through the tubes so screened. This is shown in the drawings, the direction of the heating and the cooling air currents being indicated by the arrows. The supply of air from above thus insures the more rapid cooling of the screened portion of the tubes.

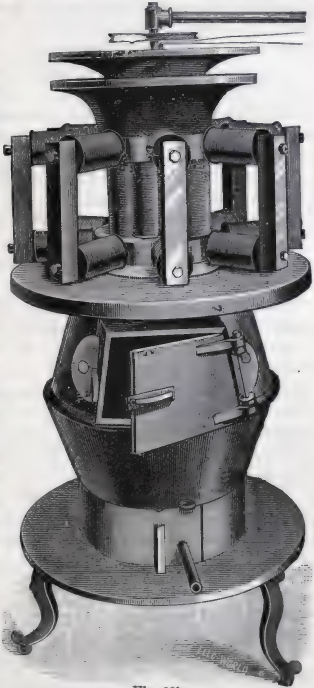


Fig. 324.

Pyromagnetic Generator or Dynamo.—An apparatus for producing electricity directly from the burning of fuel.

The operation of the generator is dependent on the fact,

that any variation in the number of lines of magnetic force that pass through a conductor, will develop differences of electric potential therein. Such variations may be effected either by varying the position of the conductor as regards the magnetic field, or by varying the intensity of the magnetic field itself. The latter method of generating differences of potential is utilized in the pyromagnetic generator, and is effected in it by varying the magnetization of rolls of thin iron by the action of heat.

A form of pyromagnetic generator devised by Edison is shown in Figs. 324 and 325.

Eight electro-magnets are provided each with an armature, consisting of a roll of corrugated iron. Each of these armatures is provided with a coil of insulated wire wound on it and protected by asbestos paper. These armatures pass through two iron discs as shown. The armature coils are connected in series in closed circuit, the wires from the coils being connected with metallic brushes that rest on a commutator, supported on a vertical axis. A pair of metallic rings is provided above the commutator to carry off the current generated. The vertical axis is provided below with a semicircular screen called a *guard plate* which rotates with the axis and cuts off or screens one-half the iron armatures from the heated air.

When the axis is rotated, the differences in the magnetization of the armatures, when hot and cold, develop differences in electromotive force which result in the production of an electric current.

Pyrometer.—An instrument for determining temperatures higher than those that can be readily measured by thermometers.

Pyrometers are operated in a variety of ways. A common method is by the expansion of a metal rod.

Pyrometer, Siemens' Electric ——— ——— —An

apparatus for the determination of temperature by the measurement of the electric resistance of a platinum wire exposed to the heat whose temperature is to be measured.

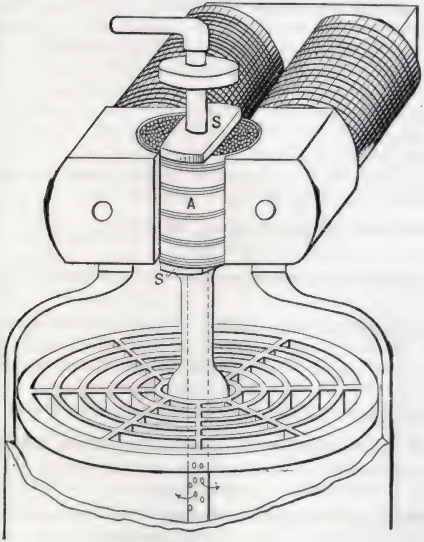


Fig. 325.

The platinum wire is coiled on a cylinder of fire-clay, so that its separate convolutions do not touch one another. It is protected by a platinum shield, and is exposed to the temperature to be measured while inside a platinum tube.

The resistance of the platinum coil at 0° C. having been

accurately ascertained, the temperature to which it has been exposed can be calculated from the change in its resistance when exposed to the unknown temperature.

Pyrometer, Siemens' Water ——— —A pyrometer employed for determining the temperature of a furnace, or other intense source of heat, by calorimetric methods, *i. e.*, by the increase in the temperature of a known weight of water, into which a metal cylinder of a given weight has been put, after being exposed for a given time to the source of heat to be measured.

When copper cylinders are employed, the instrument possesses a range of temperature of 1800° F.; when a platinum cylinder is used, it has a range of 2700° F.

Quadrant Electroscope, Henley's ——— — (See *Electroscope, Quadrant, Henley's.*)

Quadrant Electrometer.—(See *Electrometer, Quadrant.*)

Quadruplex Telegraphy.—A system of telegraphy by means of which four messages can be simultaneously transmitted over a single wire, two in one direction, and two in the opposite direction.—(See *Telegraphy, Quadruplex.*)

Qualitative Analysis.—(See *Analysis.*)

Quality of Disruptive Discharge, How Affected. —The appearance of the disruptive discharge as affected by a variety of circumstances.—(See *Discharge, Disruptive.*)

Quality or Timbre of Sound.—That peculiarity of a musical note which enables us to distinguish it from another musical note of the same tone or pitch, and of the same intensity or loudness, but sounded on another instrument.

The middle C, for example of a pianoforte, is readily distinguishable from the same note on a flute, or on a violin; that is to say, its quality is different. The differences in the quality of musical sounds are caused by the admixture of additional

sounds called *overtones* which are always associated with any musical sound.

Briefly, nearly all so-called simple musical sounds, are in reality chords or assemblages of a number of different musical sounds.

One of these notes is far louder than all the others and is called the *fundamental tone* or note, and is what is recognized by the ear as the note proper. The overtones are too feeble to be heard very distinctly, but their presence gives to the note proper its own peculiar quality. In the case of a note sounded on the flute, these overtones are different either in number or in their relative intensities from the same note sounded on another instrument. Their fundamental tones, however, are the same.

The peculiarities which enable us to distinguish the voice of one speaker or singer from another are due to the presence of these overtones. The over-tones must be correctly reproduced by the diaphragm of the telephone, or phonograph, graphophone, or gramophone, if the articulate speech is to be correctly reproduced with all its characteristic peculiarities.

Quantitative Analysis.—(See *Analysis.*)

Quantity, Arrangement of Voltaic Cells for ——
—A term, now generally in disuse, to indicate the grouping of voltaic cells, technically known as *parallel* or *multiple-arc.*

The arrangement or coupling of a number of voltaic cells in multiple-arc being an arrangement that reduces the internal resistance of the battery, and thus permits a greater current, or quantity of electricity to pass; hence the origin of the term.

Quantity, Unit of Electric ———— —A definite amount or quantity of electricity called the *coulomb.*—(See *Coulomb.*)

Although the exact nature of electricity is unknown, yet it acts like a fluid (a liquid or gas) and can be accurately measured as to quantity.

A current of one ampère, for example, is a current in which one *coulomb of electricity* passes in every second.

A condenser of the *capacity* of one *farad* is large enough to hold one *coulomb* of electricity if *forced* into the vessel under an electro-motive force of one *volt*.—(See *Capacity. Farad. Volt.*)

Quiet Discharge.—(See *Discharge, Convective.*)

Radiant Energy.—Energy transferred to, or charged on, the universal ether.

Radiant energy is of two forms, viz. :

(1) Obscure Radiation, or Heat.

(2) Luminous Radiation, or Light.

Radiant Matter.—(See *Matter, Radiant.*)

Radiophony.—The production of sound by a body capable of absorbing radiant energy, when an intermittent beam of light or heat falls on it.

The action of radiant energy, when absorbed by matter, is to cause its expansion by the consequent increase of temperature. This occurs even when the body is but momentarily exposed to a flash of light, but the instantaneous expansion, thus produced, immediately dies away, and by itself is indistinguishable. If, however, a sufficiently rapid succession of such flashes fall on the body, the instantaneous expansions and contractions produce an appreciable musical note.

The sounds so produced have been utilized by Bell and Tainter in the construction of the *Photophone*. (See *Photophone.*)

Radiation.—The transference of energy by means of ether waves.

Radicals.—Unsaturated atoms or molecules, in which one or more of the bonds are left open or free.

Radicals are either *Simple* or *Compound.*

The radical may be regarded as the basis to which other elements may be added, or as the nucleus around which they may be grouped.

Thus H_2O forms a complete chemical molecule, because the bonds of all its constituent atoms are saturated, thus $H — O — H$. But $H — O —$, or *hydroxyl*, is a radical, because its oxygen atom possesses one unsaturated or free bond. By combining with the radical, (NO_2), it forms nitric acid, thus $H — O — (NO_2) = H\ NO_3$.

During electrolysis, the molecule of the electrolyte is decomposed into two simple or compound radicals, called *ions*. These *ions* are respectively electro-positive or electro-negative, and are called *kathions* and *anions*. (See *Ions. Electrolysis.*)

Radiometer, Crookes' —————— —An apparatus for showing the action of *radiant matter* in producing motion from the effect of the reaction of a stream of molecules escaping from a number of easily moved heated surfaces. (See *Matter, Radiant.*)

Rail Road, or Railway, Electric —— —A railroad, or railway, the cars on which are driven or propelled by means of electric motors connected with the cars.

The electric current that drives the electric motor is either derived from storage batteries placed on the cars, or from a dynamo-electric machine or battery of dynamo-electric machines, conveniently situated at some point on the road. (See *Storage of Electricity.*) The current from the dynamo is led along the line by suitable electric conductors. This current is passed into the electric motor as the car runs along the tracks, in various ways, viz.:

(1) Placing one or both rails in the circuit of the dynamo and taking the current from the tracks by means of sliding or rolling contacts connected with the motor.

(2) By placing the conducting wires parallel to each other in a longitudinally slotted undergroumd conduit in the road bed, and taking the current by means of a traveling brush or roller, called a plow, sled or shoe, and provided with two central plates, insulated from one another and connected respectively to the motor terminals. On the movement of the

car over the track, these traveling contacts touch the two parallel line conductors in the conduit, and take the electric current therefrom. (See *Plow*, *Sled.*)

(3) By placing the line conductors on poles, along the road, and taking the current therefrom by means of suitable traveling contacts called trolleys or by sliders. (See *Trolleys.*)

The first method, viz., that of using the tracks alone as conductors is not much employed.

The use of the track and ground as a return for the current is now very generally employed.

In some systems the track is divided into sections which are successively brought into action with the main conductors by contacts effected by the attraction between magnets carried on the car and contact pieces of magnetic material placed below the surface. The rail section thus temporarily energized is placed in connection with the motor.

In order to regulate the speed, various devices are employed to vary the current strength in the motor circuit. These devices consist essentially in rheostats or resistances introduced into, or removed from, the motor circuit by the movement by hand of a lever that forms part of the circuit, over contact plates connected to the resistance coils.

In order to change the direction of the car, the direction of rotation of the electric motor is changed. This is effected by some form of reversing gear or mechanism that changes the direction of rotation of the motor, either by shifting the brushes, by changing the field, or by any other means. (See *Telpherage. Electric Motor. Rheostat.*)

Ray, Electric ——— —(See *Fishes, Electric.*)

Rays, Actinic ——— —(See *Antinic Rays.*)

Reaction Principle of Dynamo-Electric Machines.—The reaction of the field magnets and the armature of a dynamo-electric machine on each other until the full working current which the machine is capable of developing is produced,

When the armature of a series or shunt dynamo commences to rotate, the differences of potential generated in its coils are very small, since the field of the magnet is so weak. The current so produced in the armature, however, circulating through the field magnet coils, increases the intensity of the magnetic field of the machine, and this reacting on the armature results in a more powerful current through it. This current again increases the strength of the magnetic field of the machine, which again reacts to increase the current strength of the armature coils, and this continues nntil the machine is producing the full current it is designed to produce.

A dynamo-electric machine very rapidly "*builds up*," or reaches its maximum current after starting. The reaction principle was discovered by Soren Hjorth, of Copenhagen.

Reaction Telephone.—An *electro-magnetic* telephone in which the currents induced in a coil of wire attached to the diaphragm are passed through the coils of the electro-magnet and thus react on and strengthen it.

Reaction Wheel, Electric ——— —(See *Flyer, Electric.*)

Reactions, Anodic and Kathodic——— —(See *Kathodic and Anodic Reactions.*)

Reading Telescope.—(See *Telescope, Reading.*)

Receiver, Harmonic ——— —A receiver, employed in systems of harmonic telegraphy, containing an electro-magnetic reed, tuned to vibrate to one note or tone only. (See *Telegraphy, Harmonic.*)

Receiver, Phonographic, Telephonic, Graphophonic, Gramophonic ——— — The apparatus employed in a telephone, phonograph, graphophone, or gramophone, for the reproduction of articulate speech. (See *Phonograph.*)

Reciprocals.—The quotient arising from dividing unity by any number.

The reciprocal of 4 is $\frac{1}{4}$ or .250.

The conducting power of any circuit is equal to the reciprocal of its resistance, or, in other words, the conducting power is inversely proportional to the resistance.

The following table contains the reciprocals of the numerals up to 100:

Table of Reciprocals.

No.	Reciprocal.	No.	Reciprocal.	No.	Reciprocal.	No.	Reciprocal.	No.	Reciprocal.
2	0.5000	22	0.0455	42	0.0338	62	0.0161	82	0.0122
3	0.3333	23	0.0435	43	0.0233	63	0.0159	83	0.0120
4	0.2500	24	0.0417	44	0.0227	64	0.0156	84	0.0119
5	0.2000	25	0.0400	45	0.0222	65	0.0154	85	0.0118
6	0.1667	26	0.0385	46	0.0217	66	0.0152	86	0.0116
7	0.1429	27	0.0370	47	0.0213	67	0.0149	87	0.0115
8	0.1250	28	0.0357	48	0.0208	68	0.0147	88	0.0114
9	0.1111	29	0.0345	49	0.0204	69	0.0145	89	0.0112
10	0.1000	30	0.0333	50	0.0200	70	0.0143	90	0.0111
11	0.0909	31	0.0323	51	0.0196	71	0.0141	91	0.0110
12	0.0833	32	0.0313	52	0.0192	72	0.0139	92	0.0109
13	0.0769	33	0.0303	53	0.0189	73	0.0137	93	0.0108
14	0.0714	34	0.0294	54	0.0185	74	0.0135	94	0.0106
15	0.0667	35	0.0286	55	0.0182	75	0.0133	95	0.0105
16	0.0625	36	0.0278	56	0.0179	76	0.0132	96	0.0104
17	0.0588	37	0.0270	57	0.0175	77	0.0130	97	0.0103
18	0.0556	38	0.0263	58	0.0172	78	0.0128	98	0.0102
19	0.0526	39	0.0256	59	0.0169	79	0.0127	99	0.0101
20	0.0500	40	0.0250	60	0.0167	80	0.0125	100	0.0100
21	0.0476	41	0.0244	61	0.0164	81	0.0123		

(*Clark & Sabine.*)

Record, Gramophonic, Graphophonic, or Phonographic ——— —The irregular indentations, cuttings, or tracings made by a point attached to the diaphragm spoken against, and employed in connection with the receiving diaphragm for the reproduction of articulate speech.

Record, Telephonic ——— —A permanent record produced by the diaphragm of a telephone.

Various methods have been proposed for telephone records, but none of them have yet been introduced into actual commercial use.

Recorder, Bain's Chemical ——— —An apparatus for recording the dots and dashes of a Morse telegraphic dispatch, on a sheet of chemically prepared paper.

A fillet of paper soaked in some chemical substance, such as ferro-cyanide of potassium, is moved at a uniform rate between the two terminals of the line, one of which is iron tipped, so that on the passage of the current, a blue dot, or dash, will be made on the paper according to the length of time the current is passing.

In order to ensure a moist condition of the paper fillet some deliquescent salt, like ammonium nitrate, is generally mixed with the ferro-cyanide of potassium.

A Bain Recorder is shown in Fig. 326. A, is a drum of brass, tinned on the outside. The paper fillet is drawn from the roll and kept pressed against the cylinder A, by a small wooden roller B. The needle, which is a metallic point, is in connection with one end of the line wire, and the brass drum is connected with the other end through the earth. Care must be observed to connect the needle point with the positive electrode, as otherwise the paper will not be marked.

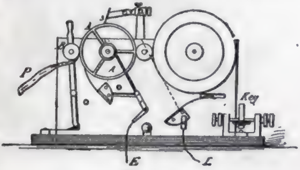


Fig. 326.

The Bain Recorder is now almost entirely replaced by the *Morse Sounder.*

Recorder, Morse —— or Morse Register.—An apparatus for automatically recording the dots and dashes of a Morse telegraphic dispatch, on a fillet of paper drawn

under an indenting or marking point on a striking lever, connected with the armature of an electro-magnet.

The Morse registering or recording apparatus is shown in Fig. 327.

The paper fillet passes between a pair of rollers *r*. driven by the clockwork W. The upper roller is provided with a groove, so that the depression of the stylus at the bent end of the lever L, by the electro-magnet M, moving its armature attached to the lever L, may indent or emboss the paper fillet. When no current is passing, the armature of the magnet and the lever L, are drawn back by the action of an adjustable spring at *n*.

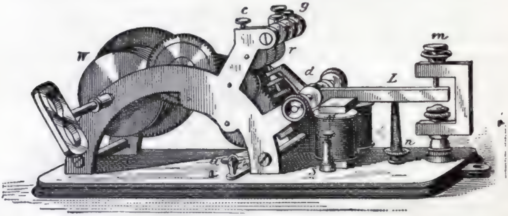


Fig. 327.

In the drawing, the ordinary Morse sounder is shown on the right. The sounder has almost entirely replaced the recording apparatus.

Recorder, Siphon ———— — An apparatus for recording in ink on a sheet of paper, by means of a fine glass siphon supported on a fine wire, the message received over a cable.

One end of the siphon dips in a vessel of ink. The record is received on a fillet of paper moved mechanically under the siphon. The ink is discharged from the siphon by electric charges imparted to the ink by a static electric machine.

In the annexed sketch of the siphon recorder, Fig. 328, a light rectangular coil *b b*, of very fine wire, is suspended by a fine wire *f f'*, between the poles N, S, of a powerful compound permanent magnet, and moving on the vertical axis of the supporting wire *f f'*, adjustable as to tension, at *h*. A stationary soft iron core *a*, is magnetized by induction

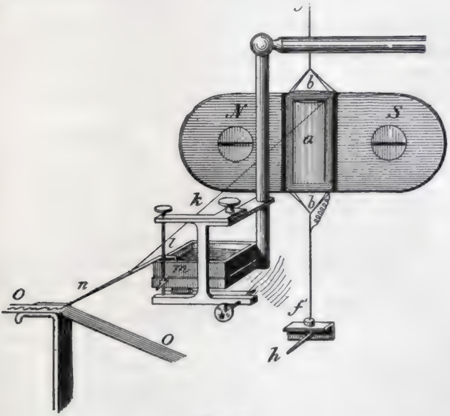


Fig. 328.

and strengthens the magnetic field of N, S. The cable current is received by the coil *b b*, through the suspending wire *f f'*, and is moved by it to the right or the left, according to its direction, to an extent that depends on the current strength.

The fine glass siphon *n*, which dips into a reservoir of ink at *m*, is capable of movement on a vertical axis *l*, and is moved backwards or forwards, in one direction by a thread *k*,

attached to *b*, and in the opposite direction by a retractile spring attached to an arm of the axis *l*.

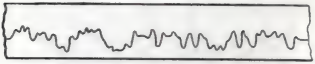
As the paper is moved under the point of the siphon, an irregular curved line is marked thereon.

Two records as actually received by a siphon recorder are shown in the Figs. 329 and 330. Movements upwards correspond to the dots, and downwards to dashes.

Rectilinear Currents. (See *Currents, Rectilinear.*)

Reflecting Galvanometer.—(See *Galvanometer, Reflecting.*)

Reflector, Parabolic ——— —(See *Parabolic Reflector.*)



S I P H O N R E C O R D E R

Fig. 329.

Reflectors.—Plane or curved surfaces capable of regularly reflecting light. (See *Parabolic Reflectors.*)

Refraction, Double ——— —The property possessed by certain bodies of splitting up by refraction a ray of light passed into it, into two separate rays, and thus doubly refracting it.

S E T T L E D

Fig. 330.

Certain specimens of calc spar possess the property of double refraction. Each of the two rays into which the original ray is separated is polarized.

Refraction, Double Electric —— ——— —The property of doubly refracting light acquired by some transparent substances when placed in an electrostatic or electro-magnetic field. (See *Double Refraction, Electric.*)

Register, Watchman's Electric ——— —(See *Watchman's Register, Electric.*)

Registering Apparatus, Electric ———— —Devices for obtaining permanent records by electrical means. (See *Recorders.*)

Regulation, Automatic ——— —(See *Automatic Regulation.*)

Relative Calibration.—(See *Calibration, Absolute and Relative.*)

Relay Bell.—(See *Bell, Relay.*)

Relay, Microphone ——— —(See *Microphone Relay.*)

Relay, or Receiving Magnet.—An electro-magnet employed in systems of telegraphy provided with contact-points, placed on a delicately supported armature, the movements of which throw a battery, called the *local battery,* into or out of circuit, for the operation of the recording apparatus.

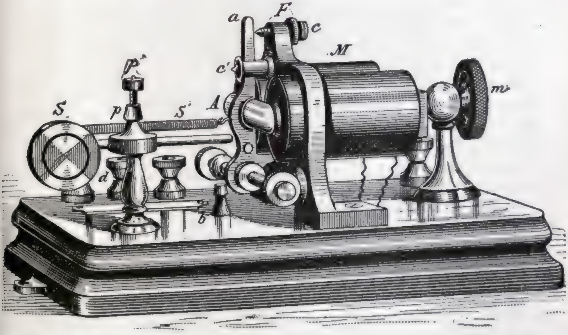


Fig. 331.

The use of a relay permits much smaller currents to be used than could otherwise be done, since the electric impulses, on reaching a distant station, are required to do no other work than attracting a delicately poised movable contact, and thus, by throwing a local battery into the circuit of the receiving apparatus, to cause such local battery to perform the work of

registering. Its use is especially required in the Morse system of telegraphy in order to cause the *Sounder* to be distinctly heard.

A form of relay much used is shown in Fig. 331.

The electro-magnet M, is wound with many turns of very fine wire. In the form used by the Western Union Telegraph Company, there are about 8,500 turns, having resistance of 150 ohms. A screw *m*, is provided for moving the electro-magnet M, a slight distance in or out for the purposes of adjustment. A semi-cylindrical armature A, of soft iron, is attached to the insulated armature lever *a*, the lower end of which is supported by a steel arbor, which is pivoted between two set screws. A retractile spring S′, regulable at S, is provided for moving the armature away from the electro-magnet. There are four binding posts, two of which are placed in the circuit of the electro-magnet, and two in that of the local battery. The ends of the line wire are connected with the former, and the receiving instrument placed in the circuit of the latter. A platinum contact is placed on the end of a screw supported at F, opposite a similar contact, near the end *a*, of the armature lever. The contact is regulable by means of a screw *c*.

On the the energizing of the electro-magnet, the attraction of its armature closes the platinum contact, and by thus completing the circuit of the local battery causes an attraction of the armature of the receiving apparatus. On the cessation of the current in the main line, the spring S′, pulls the armature away from the magnet, breaks the current of the local battery, and thus permits a similar spring on the receiving instrument to pull its armature away. Thus all the movements of the armature of the relay are reproduced with increased intensity by the armature of the receiving instrument.

The connections of the relay to the local battery and the registering apparatus, will be better understood from an inspection of Fig. 332, which represents a form of relay much

used in Germany. The retractile spring *f*, is regulated by the up-and-down movements of its lower support, which slides in the vertical pillar S. The line wire is shown at *m m*, connected at one end to earth by the *ground wire*. The registering apparatus, R, is connected in the circuit of the local battery L, as shown. The contacts are made by the end B, of the lever B B′, attached to the armature A, of the electro-magnet M M.

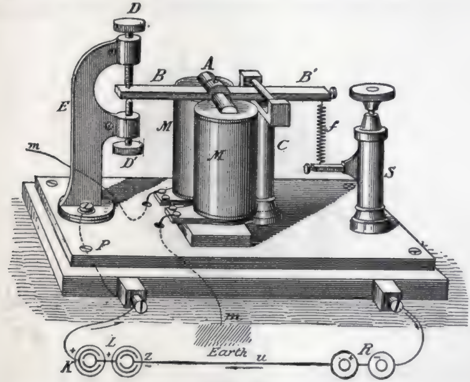


Fig. 332.

Relay, Polarized ——— —A telegraphic relay provided with a permanently magnetized armature in place of the soft iron armature of the ordinary instrument.

In the form of polarized relay shown in Fig. 333, N S, is a *steel magnet*, whose magnetism is consequently permanent, with its north and south poles at N and S, respectively. The cores of the electro-magnet *m m′*, are of soft iron, and, since they rest on the north pole N of the permanent steel magnet

the poles, brought very near together by the armatures at n, n', will be of the same polarity as N, *when no current is passing through the coils m, m'*; but when such current does pass, *one of these poles becomes of stronger north polarity, while the other changes its polarity to south.* By this means to-and-fro movements of the armature lever with its contact point are effected without the use of a retractile spring; movement in one direction occurring on the closing of the circuit through the electro-magnetism developed by the coils

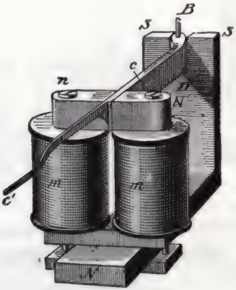


Fig. 333.

m, m', and movement in the opposite direction, on the losing of this magnetism on breaking the circuit, by the permanent magnetism of the steel magnet N S. These movements are imparted to the soft iron lever c c', pivoted at B, and passing between the closely approached soft iron poles at n, n'. This lever rests at the end c' against a contact point when moved in one direction, and against an insulated point when moved in the opposite direction. It rests against the insulated point when no current is passing through the coils m, m'.

If the armature lever were placed in a position exactly mid-

way between the poles n and n', it would not move at all, being equally attracted by each; but if moved a little nearer one pole than the other, it would be attracted to, and rest against, the nearer pole.

When alternating currents are employed on the line, the lever $c\ c'$ must be adjusted as nearly as possible in the middle of the space between n and n', in which case it will remain on the side to which it was last attracted, until a current in the opposite direction moves it to the other side.

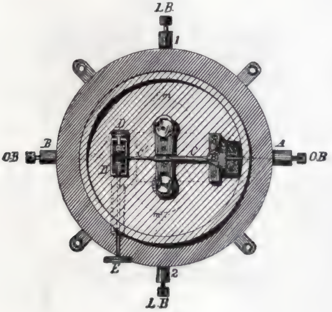


Fig. 334.

The space between the magnet poles n, n', and the contacts of the armature lever at D and D′, are shown in detail in Fig. 334, which is a plan of the preceding figure. The *binding posts*, for the line battery are shown at L B, and those for the local battery at O, B. The dotted lines show the connections.

Since the polarized relay dispenses with the retractile spring, it is far more sensitive than the ordinary instrument.

Once adjusted no further regulation is required, in which respect, it differs very decidedly from non-polarized relays.

Reluctance, Magnetic ——— —(See *Magnetic Reluctance.*)

Repeaters, Telegraphic ——— —Teregraphic devices, whereby the relay, sounder, or registering apparatus is caused to repeat the signals received, by opening and closing another circuit with which it is suitably connected.

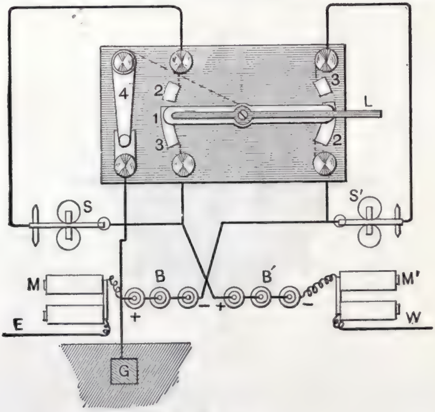


Fig. 335.

Repeaters are employed to establish direct communication between very distant stations, or to connect branch lines to the main line.

Fig. 335, shows Wood's Button Repeater. This repeater consists simply of a three-point-switch L, capable of being

placed on the points 1, 2 and 3; and a *ground switch* at 4. The circuits are arranged between the sounders S, S′, relays M, M′, main batteries B, B′, and the two main lines E and W, in the manner shown.

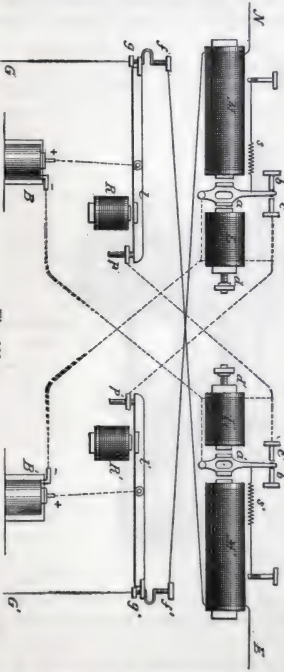


Fig. 336.

If the lever L, is in the position shown in the drawing, the lines E and W, form independent circuits.

If the ground switch 4 is closed, and the lever L is placed on 2, 2, the eastern line repeats into the western. If the lever L is placed on the plates 3, 3, the western line repeats into the eastern.

This repeater is non-automatic and can be worked in but one direction; morever, it requires the services of an attendant.

The automatic repeater can be operated in both directions, and dispenses with the constant services of an attendant at the repeating station.

In sending a dispatch through a repeater, the dots and dashes are prolonged so as to

give the lever of the repeating instrument time in which to move backwards and forwards.

In *Hicks' Automatic Button Repeater*, shown in Fig. 336, the switch or circuit changer is automatic in its action.

The relay magnets are shown at M, M′, the sounders at R, and R′; *f*, *f*′, are platinum contacts operated by levers *l* and *l*′, and L and L′ are *Extra Local Magnets*, that act on armatures placed directly opposite the armatures of the relay magnets.

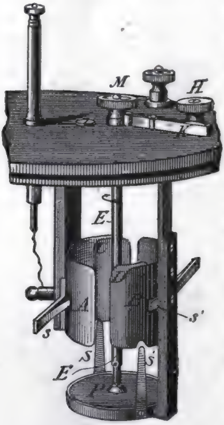


Fig. 337.

The extra local magnet L is cut out of the circuit of B′, the *Extra Local Battery*, when the main circuit is broken, and the armature is in contact with *c*. As soon as this happens, however, the spring *s*, drawing away the armature, and thus opening the short circuit of no resistance between *c* and *a*, establishes a circuit through L. On *a* coming in contact with *c*, the circuit is again broken. The tension of the spring *s* is so regulated that a very rapid vibration of *a* is so constantly maintained, that it is impossible to close the main circuit when L is not cut out. The armature *a* will therefore respond to very weak impulses of the relay magnet.

On breaking the *western main circuit* N, the lever *a* vibrates very rapidly. The lever *l*, of the sounder R, first breaks the circuit of L, and afterwards that of the *eastern main* circuit E, which passes though M. Both L′ and M′, being broken, a slight tension of *s*′, will hold *a*, in place, thus avoiding the breaking of the western main circuit through

the closing of the local circuit through R. On the closing of the western circuit, the reverse of these operations occur.

The author has taken the above explanation mainly from Pope's work on "Modern Practice of the Electric Telegraph."

Replenisher, Thomson's ————— —A static influence machine devised by Sir Wm. Thomson for charging the quadrants of his quadrant electrometer.

Two brass carriers C and D, shown in Fig. 337, are eccentrically fixed to the end of the vulcanite rod E, which is capable of rotation by the thumb screw at M, in the direction shown by the arrow. Hollow metal half cylinders, A and B, act as inductors, a strip of brass fixed around the edges of a piece of vulcanite P, connecting the metallic springs S and S′, as shown. The action of the replenisher is readily understood from the following considerations, as suggested by Ayrton in his "Practical Electricity":

A and B, Fig. 338, are two insulated hollow metallic vessels having a small difference of potential between them, A, being the higher. C and D, are two small uncharged conductors held by insulating strings. If C and D be held near A and B, as shown, the potential of C will, by induction, be raised somewhat above that of D, so that when connected by a conductor, such as the metallic wire W, a small quantity of positive electricity will flow from C to D, thus leaving D positively, and C negatively charged.

If, now, C and D, are removed from W and placed in the bottom of B and A, as shown in Fig. 339, the difference of potential between A and B, will be thereby increased, and if they are then withdrawn, and totally discharged, and again placed in the first position shown, an additional charge can be given to A and B, and this can be repeated as often as desired.

In the replenisher, A and B correspond to the vessels A and B; the brass carriers C and D, to the balls C and D,

and the spring S S, and M, to the wire W. No initial charge need be given to A and B, since they are invariably found to be at a sufficient difference of potential to build up the charge.

Residual Atmosphere.—(See *Atmosphere, Residual.*)

Residual Charge.—(See *Charge, Residual.*)

Residual Magnetism.—The magnetism remaining in the core of an electro-magnet on the opening of the magnetizing circuit.

Resin.—A general term applied to a variety of dried juices of vegetable origin.

Resins are, in general, transparent, inflammable solids, soluble in alcohol, and are non-conductors of electricity. Rosin is one of the varieties of resin.

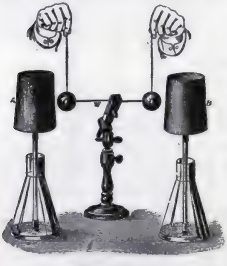


Fig. 338.

Fig. 339.

Resinous Electricity.—A term formerly employed in place of negative electricity.

It was at one time believed that all resinous substances are negatively electrified by friction. This we now know to be untrue, the nature of electrification depending as much on the character of the rubber, as on the character of the thing

rubbed. Thus resins rubbed with cotton, flannel or silk, become negatively excited, but rubbed with sulphur or guncotton, *positively* excited. The terms positive and negative are now exclusively employed.

Resistance Box.—A box containing a number of coils of known resistances employed for determining the value of an unknown resistance. (See *Box, Resistance. Balance, Electric, Box Form of.*)

Resistance Coil.—A coil of insulated wire of known resistance doubled on itself before winding, so as to neutralize the external effects of its own magnetic field. (See *Coils, Resistance.*)

Resistance Coil, Standard ——— ——— —A coil the resistance of which is that of the standard ohm.

The standard ohm, as issued by the Electric Standards Committee of England, has the form shown in Fig. 340. The coil of wire is formed of an alloy of platinum and silver, insulated by silk covering and melted paraffine. Its ends are soldered to thick copper rods r, r', for ready connection with mercury cups. The coil is at B. The space above it at A is filled with paraffin, except at the opening t, which is provided for the insertion of a thermometer

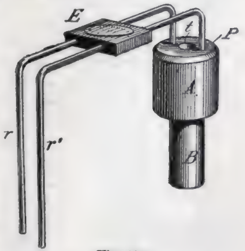


Fig. 340.

Resistance, Effect of Heat on Electric ——— —Nearly all metallic conductors have their electric resistance increased by an increase of temperature.

The carbon conductor of an electric incandescent lamp on the contrary, has its resistance decreased when raised to electric

incandescence. The decrease amounts to about three-eighths of its resistance when cold.

The effects of heat on electric resistance may be summarized as follows:

(1) The electric resistance of metallic conductors increases as the temperature rises. (Carbon is an exception).

(2) The electric resistance of electrolytes decreases as the temperature rises.

(3) The electric resistance of dielectrics and non-conductors decreases as the temperature rises.

Resistance and Conductivity of Pure Copper at Different Temperatures.

Centigrade Temperature.	Resistance.	Conductivity.	Centigrade Temperature.	Resistance.	Conductivity.
0°	1.00000	1.00000	16°	1.06168	.94190
1	1.00381	.99624	17	1.06563	.93841
2	1.00756	.99250	18	1.06959	.93494
3	1.01135	.98878	19	1.07356	.93148
4	1.01515	.98508	20	1.07742	.92814
5	1.01896	.98139	21	1.08164	.62452
6	1.02280	.97771	22	1.08553	.92121
7	1.02663	.97406	23	1.08954	.91782
8	1.03048	.97042	24	1.09365	.91445
9	1.03435	.96679	25	1.09763	.91110
10	1.03822	.96319	26	1.10161	.90776
11	1.04199	.95970	27	1.10567	.90443
12	1.04599	.95603	28	1.11972	.90113
13	1.04990	.95247	29	1.11382	.89784
14	1.05406	.94893	30	1.11782	.89457
15	1.05774	.94541			

(*Latimer Clark.*)

The following table from Matthiessen's measurements gives the relative resistances of equal lengths and cross sections

of different substances as compared with silver. The substances are chemically pure.

Legal Microhms.

Names of Metal.	Resistance in Microhms at 0° C.		Relative Resistance.
	Cubic Centimetre.	Cubic inch.	
Silver, annealed	1.504	0.5921	1.
Copper, annealed	1.598	0.6292	1.063
Silver, hard drawn	1.634	0.6433	1.086
Copper, hard drawn	1.634	0.6433	1.086
Gold, annealed	2.058	0.8102	1.369
Gold, hard drawn	2.094	0.8247	1.393
Aluminium, annealed	2.912	1.1470	1.935
Zinc, pressed	5.626	2.215	3.741
Platinum, annealed	9.057	3.565	6.022
Iron, annealed	9.716	3.825	6.460
Nickel, annealed	12.47	4.907	8.285
Tin, pressed	13.21	5.202	8.784
Lead, pressed	19.63	7.728	13.05
German Silver	20.93	8.240	13.92
Antimony, pressed	35.50	13.98	23.60
Mercury	94.32	37.15	62.73
Bismuth, pressed	131.2	51.65	87.23

(*Ayrton.*)

The above resistances are for chemically pure substances only. Slight impurities produce very considerable changes in the resistance.

Resistance, Electric ———— —The ratio between the electro-motive force of a circuit and the current that passes therein.

Ordinarily the resistance of a circuit may be conveniently regarded as that which *opposes* or *resists* the passage of the

current. Strictly speaking, however, this is not true, since from *Ohm's law* (See *Ohm's Law*),

$C = \frac{E}{R}$, from which we obtain

$R = \frac{E}{C}$, which shows that resistance is a ratio between the electro-motive force that causes the current and the current so produced.

Resistance may be expressed as a velocity. The dimensions of resistance in terms of the electro-magnetic units are

$$\frac{L}{T}.$$

(See *Units, Electro-Magnetic.*) But these are the dimensions of a velocity which is the ratio of the distance passed over in unit time. Resistance may therefore be expressed as a velocity.

"The resistance known as 'one ohm' is intended to be 10^9 absolute electro-magnetic units, and therefore is represented by a velocity of 10^9 centimetres or ten million metres (one earth-quadrant) per second"—*Sylvanus Thompson.*

Resistance may be represented by a velocity, one ohm being the resistance of a wire, which, if moved through a unit field of force at the rate of ten million (10^9) centimetres per second will have a current of one ampère generated in it. (See *Ohmic Resistance. Spurious Resistance.*

The unit of resistance is the ohm. Its true value, as has been shown by careful measurements, is not exactly equal to 10^9 centimetres per second.

Resistance, Electric ——— of Liquids.—The resistance offered by a liquid mass to the passage of an electric current.

As a rule the electric resistance of a liquid is enormously higher than that of metallic bodies, with the single exception of mercury.

To determine the resistance of a liquid, a section is taken

between two parallel metallic plates A and B, Fig. 341, placed as shown in the figure, and an electric current is passed between them. In order to avoid the effect of a *spurious resistance*, due to a *counter electro-motive force*, it is necessary to use plates at A and B, of metals that are not acted on chemically by the liquid on the passage of the current. (See *Counter Electro-Motive Force. Spurious Resistance.*)

In order to more accurately vary the size of the plates immersed in the liquid, and hence the area of cross section of the liquid conductor, as well as the distance between the plates, the apparatus shown in Fig. 342 may be used, in which these distances are readily adjustable, as shown.

Resistance, Magnetic —— — (See *Magnetic Resistance.*)

Resistance, Measurement of ——— — Methods employed for determining the resistance of any circuit or part of a circuit.

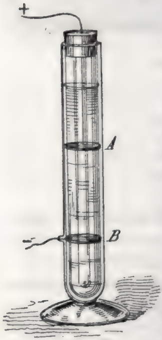


Fig. 341.

Numerous methods are employed for this purpose. Among these are:

(1) The use of a Resistance Box with a Wheatstone's Bridge, by opposing or balancing the unknown resistance against a known resistance. (See *Balance, Wheatstone's.*)

(2) With the *Differential Galvanometer.* (See *Galvanometer, Differential.*)

(3) By the *Method of Substitution.*

(4) By a *Comparison of the Deflections of a Galvanometer.*

Method of Substitution—A resistance box R, Fig. 343, galvanometer G, and the resistance x, that is to be measured, are placed in the direct circuit of the battery B by means of conductors of such thick wire that their resistance can be neglected. The deflection of the galvanometer is first measured with x in circuit, and no resist-

ance in the box R. The resistance x is then cut out of the circuit by placing a thick copper wire across the terminals of the mercury cups at m, m', and resistances unplugged in R, until the same deflection is obtained. Then, *if the electro-*

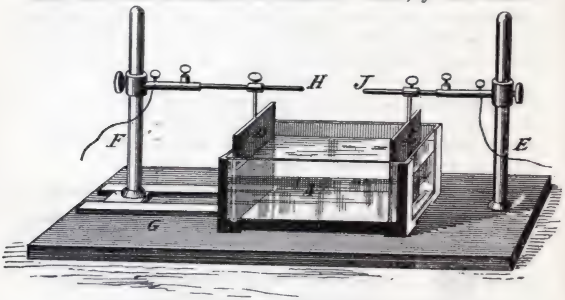


Fig. 342.

motive force of the battery has remained constant, the resistances unplugged equal the unknown resistance.

For full description of the various methods of determining resistance the reader is referred to "*Ayrton's Practical Electricity,*" "*Kempe's Handbook of Testing,*" or other standard electrical books.

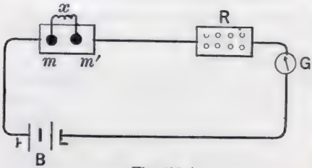


Fig. 343.

Resistance, Ohmic — —(See *Ohmic Resistance.*)

Resistance, Spurious — —(See *Spurious Resistance.*)

Resistance, Tables of — — Tables in which the resistance of equal lengths and cross sections of different substances is given in *ohms,* or other units of resistance :

RESISTANCE.

Resistance of Wires of Pure Annealed Copper at 0° C.
(Density = 8.9.)

Diameters in Millimetres.	Weight per Metre in Grammes.	Length in Metres per Kilogramme. (Bare Wire).	Resistance of Wire of Pure Annealed Copper at 0° C.		
			Ohms per Kilometre.	Metres per Ohm.	Ohms per Kilogramme.
5	175	5.7	.8	1230.5	.00456
4.4	135.28	7.4	1.06	944.38	.00784
3.9	106.35	9.5	1.35	722	.0128
3.4	80.8	12.5	1.80	563.92	.0222
3	62.93	16	2.3	439.07	.0365
2.7	51	19.8	2.8	355.65	.0557
2.4	40.23	25	3.6	281	.088
2.2	33.82	29	4.2	236.08	.123
2	27.95	36	5.1	195.15	.185
1.8	22.7	44	6.3	158.08	.278
1.6	17.89	56	8	124.9	.448
1.5	15.75	63	9.1	109.75	.574
1.4	13.7	73	10.5	95.651	.763
1.3	11.84	85	12	82.42	1.03
1.2	10.06	100	14	70.247	1.42
1.1	8.47	119	17	59.024	2.02
1	6.99	144	20	48 782	2.95
.9	5.66	178	25	39.515	4.19
.8	4.47	225	32	31.225	7.21
.7	2.83	294	42	23.9	12.3
.6	2.52	400	57	17.56	22.78
.5	1.74	576	81	12.305	46.81
.4	1.175	902	122.4	8.173	110.41
.34	.808	1251	177.9	5.622	222.55
.3	.7181	1607	228.5	4.377	367.2
.24	.4026	2508	357	2.801	895.36
.2	.2797	3614	514	1.945	1,857.6
.16	.179	5590	803.1	1.245	4,489
.12	.1007	9929	1428	.7	14,179
.1	.0699	14369	2056	.486	29,549
.08	.0447	24570	3213	.311	78,943
.06	.0252	39824	5713	.173	227,515
.04	.0112	88878	12848	.078	1,142,405

(Hospitalier.)

Table of Conducting Powers and Resistances in Ohms.

Names of Metals.	Conducting power at 0° C.	Resistance of a wire one foot long weighing one grain.	Resistance of a wire one metre long weighing one gramme.	Resistance of a wire one foot long $^1/_{1000}$ inch in diameter.	Resistance of a wire one metre long, one millimetre in diameter.	Approximate percentage of variation in resistance for 1 deg. of temperature at 20°.
Silver, annealed......	....	0.2214	0.1544	9.936	0.01937	0.377
Silver, hard drawn...	100.00	0.2421	0.1689	9.151	0.02103	....
Copper, annealed....	....	0.2064	0.1440	9.718	0.02057	0.388
Copper, hard drawn..	99.55	0.2106	0.1469	9.940	0.02104	....
Gold, annealed......	....	0.5849	0.4080	12.52	0.02650	0.355
Gold, hard drawn....	77.96	0.5950	0.4150	12.74	0.02697	....
Aluminium, annealed	....	0.06822	0.05759	17.72	0.03751	....
Zinc, pressed........	29.02	0.5710	0.3983	32.22	0.07244	0.365
Platinum, annealed..	....	3.536	2.464	55.09	0.1166	....
Iron, annealed.......	16.81	1.2425	0.7522	59.40	0.1251	....
Nickel, annealed. ..	13.11	1.0785	0.8666	75.78	0.1604	....
Tin, pressed.........	12.36	1.317	0.9184	80.36	0.1701	0.365
Lead, pressed........	8.32	3.236	2.257	119.39	0.2527	0.387
Antimony, pressed...	4.62	3.324	2.3295	216.0	0.4571	0.389
Bismuth, pressed.. .	1.24	5.054	3.525	798.0	1.689	0.354
Mercury, liquid	....	18.740	13.071	600.0	1.270	0.072
Platinum-silver, alloy, hard or annealed	....	4.243	2.959	143.35	0.3140	0.031
German silver, hard or annealed..... ...	....	2.652	1.850	127.32	0.2695	0.044
Gold, silver, alloy, hard or annealed....	....	2.391	1.668	66.10	0.1399	0.065

(*Jenkin.*)

When several resistances are placed in series in any circuit, by measuring the difference of potential at their terminals, their values can be determined by simple calculation, being directly proportional to these differences of potential. This method in especially applicable to the measurement of such low resistances as the armatures of dynamo electric machines.

Resultant.—In mechanics, a single force that represents

in direction and intensity the effects of two or more forces acting in different directions.

Retardation.—A decrease in the speed of telegraphic signaling caused by the induction of the line conductor on itself, and the induction between it and neighboring conductors.

Retardation in signaling is produced by the following causes:

(1) *Self-Induction* which produces *extra currents.* (See *Self-Induction. Currents, Extra.*)

The extra current on making, retards the beginning of the signal, and the extra current on breaking, retards its stopping.

(2) *Mutual Induction* between the line conductor and neighboring conductors. The line must receive a certain charge before a current sent into it at one end can produce a signal at the other end. This charge will depend on the length and surface of the wire, on its neighborhood to the earth or other wires, and on the nature of the insulating material between it and the neighboring conductor. This results in a charge given to the wire which is lost as a current for signaling. The greater the *electrostatic capacity* of the line wire, the greater will be the retardation in signaling. (See *Capacity, Specific Inductive. Dielectric. Electrostatic Capacity.*)

(3) The *Magnetic Inertia* or *Lag,* or the time required to magnetize or demagnetize the core of the electro-magnetic receptive devices used on the line.

Retentivity, Magnetic ——— —A term proposed by Lamont in place of *coercive force,* or the power possessed by a magnetizable substance of resisting magnetization or demagnetization. (See *Coercive Force.*)

Return Shock or Stroke. (See *Back Stroke.*)

Reverse Induced Current.—The current produced by self-induction in a circuit at the moment of completing the circuit. (See *Extra Current.*)

Reversing Gear of Electric Motor.—Apparatus for reversing the direction of the current through an electric motor, and, consequently, the direction of its rotation. (See *Railroad* or *Railway, Electric.*)

Reversing Key.—(See *Key, Reversing.*)

Rheochord.—(See *Rheostat.*)

Rheometer.—A term formerly employed for any device for measuring the strength of a current. (Now obsolete and replaced by the word *Galvanometer.*)

Rheomotor.—A term formerly employed to designate any electric source. (Now obsolete and replaced by the various names of the different electric sources. (See *Source, Electric.*)

Rheophore.—A term formerly employed to indicate a portion of a circuit conveying a current and capable of deflecting a magnetic needle placed near it. (Now obsolete.)

Rheoscope.—A term formerly employed in place of the present word Galvanoscope, for an instrument intended to show the presence of a current, or its direction, but not to measure its strength. (Now obsolete.)

Rheostat.—A term signifying any adjustable resistance.

A rheostat enables the resistance to be brought to a *stand*, *i. e.*, to a fixed value ; hence the name.

The term rheostat is applied generally to a readily variable resistance, the varying values of which are known.

Rheostat, Wheatstone's ——— —A form of apparatus sometimes employed for an adjustable resistance.

This apparatus is very seldom employed in accurate work.

The parallel cylinders A and B, Fig. 344, are respectively of conducting and non-conducting materials, the bare wire on which can be wound from either cylinder to the other. When introduced into a circuit, only the resistance of the portions of the wire on B is introduced into the circuit, since the bare wire on A is short circuited by the metallic cylinder. This

rheostat is seldom employed in accurate measurements owing to the difficulty of invariably obtaining reliable contacts.

Rheostatic Machine.—A machine devised by Planté in which continuous static effects of considerable intensity are obtained by charging a number of condensers in multiple arc and discharging them in series.

The condensers are charged by connecting them with a number of secondary or storage batteries.

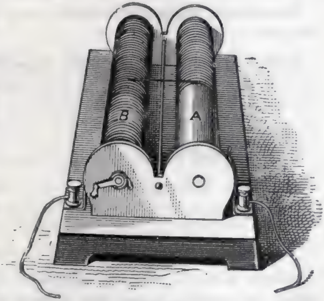


Fig. 344.

Rheotome.—A term formerly employed for any device by means of which a circuit could be periodically interrupted. (Now obsolete and replaced by *Interrupter.*)

Rheotrope. — A term formerly employed for any device by which the current could be reversed. (Now obsolete and replaced by *Commutator or Current Reverser.*)

Rhigolene.—A volatile hydro-carbon obtained during the distillation of coal oil, and employed in the flashing, or treatment of carbons. (See *Flashing of Carbons.*)

Rhumbs of Compass.—The thirty-two points of the mariners' compass. (See *Points of Compass.*)

Rigidity, Molecular ——— —Resistance offered by the molecules of a substance to rotation, or displacement.

The molecular rigidity of a magnetizable substance is now generally considered to be the cause of differences of *coercive*

force or *magnetic retentivity.* (See *Coercive Force. Retentivity, Magnetic.*)

Rings, Nobili's ——— —(See *Metallochromes.*)

Rods, Lightning ——— —(See *Lightning Rods.*)

Rotation, Electro Magnetic ——— —(See *Accumulator. Disc, Arago's. Disc, Faraday's. Motors, Electric.*)

Rotation, Magneto-Optic ——— —(See *Magneto-Optic Rotation.*

Rubber of Electrical Machine.—A cushion of leather, covered with an electric amalgam, and employed to produce electricity by its friction against the plate or cylinder of a *frictional electric machine.* (See *Machine, Frictional.*)

Ruhmkorff Coils.—(See *Induction Coils.*)

Saddles, Telegraphic ——— —Brackets placed on the top of telegraph poles, for the support of the insulators.

Saddle brackets are usually employed for the wire attached to the top of a telegraph pole. (See *Poles, Telegraphic.*)

Safety Catch, Safety Device, Safety Fuse, Safety Plug or Safety Strip for Multiple Circuits.—A wire, bar, plate, or strip of readily fusible metal, capable of conducting, without fusing, the current ordinarily employed on the circuit, but which fuses, and thus breaks the circuit, on the passage of an abnormal current. (See *Lamp, Incandescent.*)

Safety Device for Arc Lamp, or Series Circuits.—Mechanism which automatically provides a path for the current around a lamp, or other faulty electro-receptive device in a series circuit, and thus prevents the opening of the entire circuit on the failure of such device to operate. (See *Lamp Arc, Electric.*)

Safety Lamp, Electric ————— —An incandescent electric lamp, with thoroughly insulated leads, employed in

mines, or other similar places, where the explosive effects of readily ignitable substances are to be feared. Such lamps are often directly attached to a portable battery.

Salts, Electrolysis of ——— —The decomposition of a salt into its electro positive and negative *radicals* or *ions*. (See *Electrolysis.*)

Saturation, Magnetic ——— —The maximum magnetization which can be imparted to a magnetic substance.

In an electro-magnet, such a degree of magnetization, that any further increase of the magnetizing current, increases the magnetic intensity only to the comparatively small extent of the increase of the magnetic field due to the current itself. (See *Magnetic Saturation.*)

Scratch Brush.—A brush furnished with metallic bristles, and employed for cleansing the surfaces of metallic objects prior to their being electro-plated.

Screen, Methven's Standard ——— —(See *Methven's Standard Screen.*)

Screen or Shield, Electric ——— —A closed conductor, placed over a charged body to screen or protect it from the effects of external electrostatic fields.

The ability of a closed, hollow conductor to act as a screen, arises from the fact that all points on its inner surface are at the same potential, and therefore are not affected by an increase or decrease in the potential of the outside of the conductor as compared with that of the earth. (See *Net, Faraday's.*)

No considerable thickness is required for the efficient operation of an electric screen.

Screen or Shield, Magnetic ——— — (See *Magnetic Screen* or *Shield.*)

Screws, Binding ——— **or Binding Posts** — (See *Binding Posts.*)

Seal, Hermetical ——— —(See *Hermetical Seal.*)

Search-Lights, Electric ——— — (See *Lighthouse Illumination.*)

Secondary Batteries.—Arrangements of voltaic cells that derive their differences of electric potential from the action of an electric current sent through them from a separate source. (See *Storage of Electricity.*)

Secondary Clocks.—(See *Clocks, Secondary.*)

Secondary Currents.—The currents induced in the secondary coil of an induction apparatus. (See *Induction Coils.*)

In the United States this term is also applied to the currents derived from secondary batteries. The word is generally employed in the former sense.

Secondary Generators.—A term sometimes employed for transformers or converters. (See *Transformers* or *Converters.*)

Seismograph, Electric ——— —An apparatus for electrically recording the direction and intensity of earthquake shocks.

Selenium.—A comparatively rare element generally found associated with sulphur.

Selenium Cell.—A photo-electric couple consisting of selenium in combination with another metal, usually copper, and capable of producing a current by the direct action of light.

Selenium Cell, or Resistance.—A mass of crystalline selenium, the resistance of which is reduced by placing it in the form of narrow strips between the edges of broad conducting plates of brass.

The selenium employed for this purpose is the vitreous variety, which has been fused and maintained for several

hours at about 220° C. by means of which its resistance is reduced.

By exposure to sun-light, the resistance of a selenium cell is *decreased* fully one-half its resistance in the dark. The selenium cell is used in the *Photophone.* (See *Photophone.*)

Selenium Eye.—An artificial eye in which a selenium resistance takes the place of the retina and two slides the place of the eyelids.

The selenium resistance is placed in the circuit of a battery and a galvanometer. When the slides L, L, Fig. 345, are shut, the galvanometer deflection is less than when they are open.

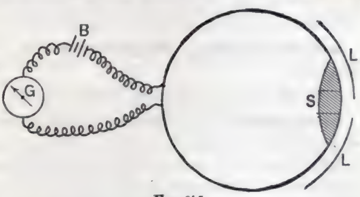


Fig. 345.

The opening of the aperture between the slides L, L, may be automatically accomplished by the action of the light itself, by moving them by an electro-magnet placed in the circuit of a local battery, and a selenium resistance so arranged that when light falls on the selenium resistance, the slides L, L, are moved together, and when the amount of such light is small, they are moved apart. In this way, there is obtained a device roughly resembling the dilatation or contraction of the pupil of the eye, from the action of light on the iris.—(See *Photometer, Selenium.*)

Self-Induction.—The induction of a current on itself, as distinguished from the induction it produces in neighboring conductors. (See *Currents, Extra.*)

Self-Induction, Coefficient of ——— —A number representing the value of the induction produced by a circuit on itself.

The coefficient of self-induction varies with the shape of the circuit, and increases with the number of coils or turns in the circuit. The retardation in long telegraph lines, where numerous coils of wire are used, or where there are long cables, is due to self-induction as well as to induction in neighboring conductors.

According to Helmholtz, as phrased by Sylvanus Thompson, "*The self induction in a circuit on making contact has the effect of diminishing the strength of the current by a quantity, the logarithm of whose reciprocal is inversely proportional to the coefficient of self-induction, and directly proportional to the resistance of the circuit, and to the time that has elapsed since making the circuit.*"

Self-Recording Magnetometer.—(See *Magnetograph.*)

Self-Winding Clocks.—(See *Clocks, Self-Winding.*)

Semaphore.—A variety of signal apparatus employed in railroad block systems.

The semaphore used on the Pennsylvania Railroad consists of a wooden post, in the neighborhood of twenty feet in height, on which a wooden arm or blade, six feet in length and a foot in width is displayed. When the block is clear, the arm is placed pointing downwards at an angle of 75° with the horizontal by day, or the semaphore displays a white light at night. When the block is not clear, the arm or blade is placed in a horizontal position by day, or displays a red light at night. (See *Block Signals.*)

Sender, Zinc —— —(See *Zinc Sender.*)

Sensibility of Galvanometer.—The readiness and extent to which the needle of a galvanometer responds to the passage of an electric current through its coils. (See *Galvanometers.*)

Separate Touch, Magnetization by —— —(See *Methods of Magnetization by Touch, Separate.*)

Separately Excited Dynamo Electric Machine.—A dynamo electric machine, whose field coils are excited by means of a source external to the machine. (See *Dynamo Electric Machine, Separately Excited.*)

Series Circuits.—(See *Circuits, Varieties of.*)

Series Connections.—The connection of a number of separate electric sources, or electro-receptive devices, or circuits so that the current passes successively from the first to the last in the circuit. (See *Circuits, Varieties of.*)

Series-Multiple Circuit.—(See *Circuits, Varieties of.*)

Series, Thermo-Electric ——— — (See *Thermo-Electric Series.*)

Shackle, Telegraphic ——— — A special form of insulation employed on a telegraph pole in order to confine to one point the strain caused by a wire leaving the insulator at a sharp angle. (See *Poles, Telegraphic.*)

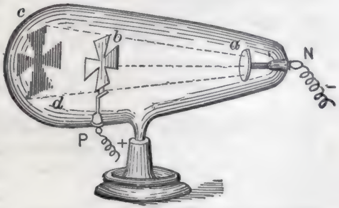


Fig. 346.

Shadow, Electric, or Molecular ——— —The comparatively dark space on those parts of the walls of Crookes' tubes, which have been protected from molecular bombardment by suitably placed screens.

If *a*, in the Crookes' tube shown in Fig. 346, be connected with the negative pole of any electric source, and the cross shaped mass of aluminium at *b*, be connected with the positive electrode, on the passage of a series of discharges, *phosphorescence* is produced by the molecular bombardment from *a*, in all parts of the vessel opposite *a*, except those lying in

the projection of its geometrical shadow. (See *Phosphorescence, Electric.*)

Shadow Photometer.—(See *Photometer, Shadow.*)

Sheet, Current —— —The sheet into which a current spreads when the wires of any source are connected at any two points near the middle of a very large and thin conductor.

A continuous electric current flows through the entire mass of a conductor, not in any single line of direction, but, if the terminals of any source are connected to neighboring parts of a greatly extended thin conductor, the current spreads out in a thin sheet known as a *current sheet*, and instead of flowing in a straight line between the points, spreads over the plate in *curved lines of flow*, which, so far as shape is concerned, are not unlike the *lines of magnetic force.*

Shells, Magnetic —— —(See *Magnetic Shells.*)

Shellac.—A resinous substance possessing valuable insulating properties, which is exuded from the roots and branches of certain tropical plants.

The specific inductive capacity of shellac as compared with air is 2.74.

Shield, Magnetic —— for Watches.—A hollow case of iron, in which a watch is permanently kept, in order to seield it from the influence of external magnetic fields. (See *Magnetic Screens or Shields.*)

Ships, Protection of —— from Lightning Strokes. —(See *Lightning Rods for Ships.*)

Ship's Sheathing, Electric Protection of—— —— —(See *Metals, Electric Protection of.*)

Shock, Electric —— —A physiological effect produced on animals by the passage through them of an electric current, generally attended by a violent contraction of the muscular fibres.

Short-Circuit.—A shunt, or by-pass, of comparatively small resistance, around the poles of an electric source, or

around any portion of a circuit, by which so much of the current passes as virtually to cut out any other circuit connected therewith, and so prevent it from receiving an appreciable current.

Short-Circuit Key.—(See *Key, Short Circuit.*)

Shunt Circuits, Resistance of —— ——— —(See *Circuits, Shunt, Resistance of.*)

Shunt Circuits, Uses of —— ——— —(See *Circuits, Shunt, Uses of.*)

Shunt Dynamo.—A dynamo electric machine the field magnet coils of which are in a shunt circuit around the external circuit of the machine. (See *Dynamo Electric Machine, Shunt.*)

Shunt, Electro-Magnetic ——— —In a system of telegraphic communication an electro magnet whose coils are placed in a shunt circuit around the terminals of the receiving relay.

The electro-magnetic shunt operates by its self induction. Its poles are permanently closed by a soft iron armature, so as to reduce the resistance of the magnetic circuit. (See *Induction, Self.*) On making the circuit in the coils of the receiving relay, a current is produced in the coils of the electro-magnetic shunt in the *opposite direction* to the relay current, and, on breaking the circuit in the relay, a current is produced in the coils of the electro-magnetic shunt in the same direction as the current in the receiving relay. The connection of the coils of the electro-magnetic shunt with those of the receiving relay, however, is such that on making the circuit in the relay the current in the shunt coils flows through the relay in the same direction, and on breaking the circuit it flows in the opposite direction. Therefore this shunt effects the following :

(1) At the commencement of each signal in the receiving relay, it produces an induced current in the same direction which strengthens the current in the relay.

(2) At the ending of each signal in the receiving relay, it produces a current in the opposite direction, which hastens the motion of the tongue of the polarized relay. (See *Relay, Polarized.*)

Shunt for Galvanometer.—(See *Galvanometer Shunt.*)

Shunt or Derived Circuit.—A branch or additional circuit provided at any part of a circuit, through which the current branches or divides, part flowing through the original circuit, and part through the new branch.

In the case of branched circuits each of the circuits acts as a shunt to the others. Any number of additional or shunt circuits may be thus provided. (See *Kirchhoff's Laws.*)

Shunt, Magnetic —— —An additional path of magnetic material provided in a magnetic circuit for the passage of the lines of force.

Shunts, Multiplying Power of —— —A quantity, by which the current flowing through a galvanometer provided with a shunt, must be multiplied, in order to give the total current.

The multiplying power of a shunt may be determined from the following formula, viz.:

$A = \left(\frac{s+g}{s}\right) \times C$, in which $\frac{s+g}{s}$ = the Multiplying Power of a Shunt whose resistance is s; g, is the galvanometer resistance; C, the current through the galvanometer; and A, the total current passing; s and g, are taken in *ohms*, and C and A, in ampères.

Suppose, for example that but 1/10 the entire current is to flow through the galvanometer, then the resistance of the shunt must evidently be $\frac{1}{9}\,g$, for,

$$\frac{s}{s+g} = \frac{1}{1+9} = \frac{1}{10};$$

or, $10\,s = s + g$. $10\,s - s = g \therefore 9\,s = g$; or $s = (\frac{1}{9})\,g$.

Sidero-Magnetic.—A term proposed by Sylvanus P. Thompson to replace the word *ferro-magnetic.*—(See *Ferro-Magnetic.*)

Siemens and Halske Voltaic Cell.—(See *Cell, Voltaic.*)

Signals, Electro Pneumatic ——— —Signals operated by the movements of diaphragms or pistons moved by compressed air, the escape of which is controlled electrically.

Signaling, Velocity of Transmission of ——— —The speed or rate at which successive signals can be sent on any line without the retardation producing serious interference. (See *Retardation of Signals.*)

Silurus electricus.—The electric eel.—(See *Electric Eel.*

Silver Bath.—(See *Baths, Silver, etc.*)

Simple Magnet.—(See *Magnet, Simple.*)

Simple Voltaic Cell.—(See *Cell, Voltaic.*)

Sine Galvanometer.—(See *Galvanometer, Sine.*)

Single Fluid Cell.—A voltaic cell in which both elements of the couple are immersed in the same electrolyte. (See *Cell, Voltaic Single Fluid.*)

Single Fluid Electrical Hypothesis.—A hypothesis framed to explain the phenomena of electricity on the assumption of a single electric fluid possessed by all matter. (See *Electricity, Single Fluid Hypothesis of.*)

Single Touch.—A method of magnetization in which the magnetizing bar is merely drawn from one end to the other of the bar to be magnetized, and returned through the air for the next stroke. (See *Magnetization, Methods of.*)

Sinistrorsal Solenoid.—(See *Solenoid, Sinistrorsal.*)

Sinuous Currents.—(See *Currents, Sinuous.*)

Siphon Recorder.—(See *Recorder, Siphon.*)

Skin, Faradization of ——— —The therapeutic treatment of the skin by a faradic current.

For efficient faradization the skin should be thoroughly dried and a metallic brush or electrode employed. For very sensitive parts, as, for example, the face, the hand of the operator, first thoroughly dried, is to be preferred as an electrode.

Skin, Human, Electric Resistance of ——— —— — The electric resistance offered by the skin of the human body.

The electric resistance of the skin is subject to marked differences in different parts of the body, where its thickness or continuity varies. It varies still more with variations in its condition of moisture. Even in the same individual the resistance varies materially under apparently similar conditions.

Sled.—The sliding contacts drawn after a moving electric railway car through the slotted underground conduit containing the wires or conductors from which the driving current is taken.

Slide Balance, Wheatstone's.—(See *Balance, Wheatstone's Electric.*)

Smee's Voltaic Cell.—(See *Cell, Voltaic.*)

Socket, Electric Lamp ——— —A support for the reception of an incandescent electric lamp.

Incandescent lamp sockets are generally made so that the mere insertion of the base of the lamp in the socket completes the connection of the lamp terminals with terminals of the socket connected with the leads that supply current to the lamp, and its removal from the socket, automatically breaks such circuit. The socket is generally provided with a key for turning the lamp on or off without removing it from the socket.

Figs. 347 and 348, show forms of lamp sockets for incandescent lamps and the details of the key for connecting or disconnecting the lamp with the leads.

Soldering, Electric ——— —The uniting of metals to one another, in which heat generaterd by the electric current is used to melt the solder in the place of ordinary heat.

Solenoid, Dextrorsal ——— —(See *Solenoid Practical.*)

Solenoid, Ideal ——— —A solenoid consisting of a cylinder built up of true circular currents, with all their faces of like polarity turned in the same direction and entirely independent of one another.

The practical solenoid differs from the ideal solenoid in that the successive circular circuits or currents are all connected with one another in series.

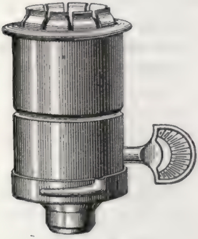


Fig. 347.

Fig. 348.

Solenoid or Helix. Electro-Magnetic Solenoid. —The name given to a cylindrical coil of wire, each of the convolutions of which is circular.

A circuit bent in the form of a helix, supported at its two extremities, as shown in Fig. 349, and traversed by an electric current, will move into the magnetic meridian of the place, and if free to move in a vertical plane, will come to rest in the line of the dip of the place.

A solenoid traversed by an electric current acquires thereby all the properties of a magnet, and is attracted and repelled by other magnets. Its poles are situated at the ends of the cylinder on which the solenoid may be supposed to be wound.

The polarity of a solenoid depends on the direction of the current as regards the direction in which the solenoid is wound.

This solenoid is sometimes called an electro-magnetic solenoid or helix, in order to distinguish it from a magnetic solenoid or *solenoidal magnet.* (See *Magnet, Solenoidal.*)

A solenoid, if suspended so as to be free to move, will come to rest in the plane of the magnetic meridian.

It will also be attracted or repelled by the approach of a dissimilar or similar magnet pole respectively, Fig. 351.

Solenoid, Practical ——— —The name applied to the ordinary solenoid in order to distinguish it from the *ideal solenoid.* (See *Solenoid, Ideal.*)

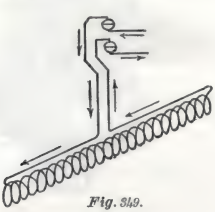


Fig. 349.

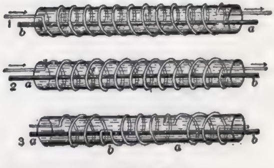


Fig. 350.

A *practical solenoid* consists, as shown in Fig. 350, of a spiral coil of wire wrapped in the manner shown in the figures at (1), (2) and (3.)

The polarity of the solenoid depends on the *direction of the current, and therefore on the direction of winding.* In any solenoid, however, the *polarity may be reversed* by reversing the direction of the current. (See *Electro-Magnet.*)

A *Right Handed, or Dextrorsal Solenoid,* is one wound in the direction shown at (1).

A *Left Handed, or Sinistrorsal Solenoid*, is one wound in the direction shown at (2).

The solenoid shown at (3) is wound so as to produce *consequent poles*. (See *Consequent Poles, or Points.*)

Solenoid, Sinistrorsal ——— —(See *Solenoid, Practical.*)

Sonometer, Hughes' ——— —A form of *induction balance* for the purpose of examining the intensity of sounds, or the delicacy of the ear in detecting or distinguishing sounds. (See *Induction Balance, Hughes.*)

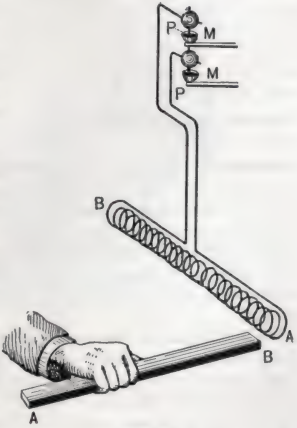


Fig. 351.

Sonorescence ——— —A term proposed for the sounds produced when a piece of vulcanite or any other solid substance is exposed to a rapid succession of flashes of light. See *Photophone.*)

Sound (Subjectively) ——— —The effect produced by a vibrating body.

Sound (Objectively). The waves in the air or other medium which produce sound.

The word sound is therefore used in science in two distinct senses, viz. :

(1.) *Subjectively*, as the sensation produced by the vibration of a sonorous body.

(2.) *Objectively*, as the waves or vibrations that are capable of producing the sensation of sound.

Sound is transmitted from the vibrating body to the ear of the hearer by means of alternate to-and-fro motions in the air, occurring in every direction around the vibrating body, and forming spherical waves called *waves of condensation* and *rarefaction*. Unlike light and heat, these waves require a tangible medium such as air, to transmit them.

Sound, therefore, is not propagated in a vacuum. The vibrations of sound are *longitudinal*, that is, the to-and-fro motions occur in the same direction as that in which the sound is traveling. The vibrations of light are *transverse*, that is, the to-and-fro motions are at right angles to the direction in which the light is traveling.

Sound, Characteristics of ——— —(See *Characteristics of Sound.*)

Sounder, Morse Telegraphic ——————— —An electro-magnet which produces audible sounds by the movements of a lever attached to the armature of the magnet.

The Morse sounder has now almost entirely supplanted the paper recorder or register. On short lines it is placed directly in the telegraphic circuit. On long lines it is operated by a *local battery*, thrown into or out of action by the *relay*. (See *Relay.*)

The Morse sounder, shown in Fig. 352, consists of an upright electro magnet M, whose soft iron armature A is rigidly attached to the striking lever B, working in adjustable screw pivots as shown. The free end of the lever is limited in its strokes by two set screws N, N. The lower of these screws is set so as to limit the approach of the armature A to the poles of the electro magnet; the upper screw is set so as to give the end B, sufficient play to produce a loud sound. A retractile spring, attached to the striking lever near its pivoted end, and provided with regulating screw S S, pulls the lever back when the current ceases to flow through M.

The dots and dashes of the Morse alphabet are reproduced by the sounder, as audible signals, that are distinguished by the operator by means of the different sounds produced by the up and down stroke of the lever as well as by the difference in the intervals of time between the successive signals.

Sounds, Magnetic ———— (See *Magnetic Sounds.*)

Source, Electric.—Anything which produces a difference of potential or an electro-motive force.

Spark Discharge.—(See *Discharge, Disruptive.*)

Spark, Length of ———— (See *Length of Spark.*)

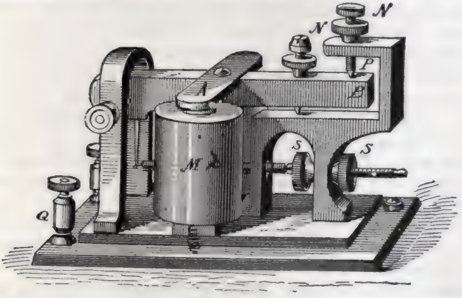


Fig. 352.

Spark Tube.—A high vacuum tube, across which the spark from an induction coil will not pass, when the vacuum is sufficiently high.

A spark tube, connected with incandescent lamps which are undergoing exhaustion, acts as a simple gauge to determine the degree of exhaustion. When an induction coil discharge ceases to pass, or to freely pass, the vacuum is considered as sufficient, according to circumstances.

Sparking of Dynamo-Electric Machines.—An irregular and injurious action at the commutator of a dynamo.

electric machine, attended with spark at the collecting brushes.

Sparking consists in the formation of small arcs under the collecting brushes. One cause of sparking is to be found in the brushes leaving one commutator strip before making connection with the next strip. Sparking causes a burning of the commutator strips, and an irregular consumption of the brushes, both of which produce further irregularities by wear or friction of the brushes against the commutator bars. Sparking from this cause may be avoided by so placing the brush as to cause it to bridge over the space between two consecutive bars, thus permitting it to touch one bar before leaving the other. Two brushes, electrically connected, are sometimes employed for this purpose, or the slots between contiguous bars are slightly inclined to the axis of rotation.

At the moment the brush touches two contiguous commutator bars, it short circuits the coil terminating at those bars. On the breaking of this closed circuit, a spark appears under the brushes. This spark is often considerable, since from the comparatively small resistance of the coil, it is apt, when short-circuited to produce a heavy current.

Another cause of sparking is to be found in the self-induction of the armature coils. The extra current on breaking forms an injurious spark under the brushes. This spark may be considerable since the current produced in the coil on momentarily short-circuiting it by the brushes simultaneously touching the adjoining commutator segments may be large.

Sparking occurs when the brushes are not set close to the neutral line. Since the principal cause for this change in the lead of the brushes is the magnetizing effect of the armature coils, it is preferable to make the number of windings of these as few as possible and to obtain the necessary differences of potential by increasing the speed of rotation and the strength of the magnetic field of the machine. Short armature coils also lessen the sparking due to *self-induction.*

Sparking at the brushes is also caused by the jumping of improperly supported or constructed brushes.

When the brushes are not set close to the neutral point long *flashing sparks* are apt to occur.

A lack of symmetry of winding of the armature coils will necessarily be attended by injurious flashing, from the impossibility of properly adjusting the brushes.

Specific Heat.—(See *Heat, Specific.*)

Specific Heat of Electricity.—A term proposed by Sir Wm. Thomson to indicate the analogies between the absorption and emisssion of heat in purely thermal phenomena, and the absorption and emission of heat in thermo electric phenomena.

As we have already seen heat is either given out or absorbed, when an electric current passes from one metal to another across a junction between them. (See *Effect, Peltier.*)

So, too, when electricity passes through an unequally heated wire the current tends to increase or decrease the differences of temperature, according to the direction in which it flows, and according to the character of the metal. (See *Effect, Thomson.*)

"If electricity were a fluid," says Maxwell, "running through the conductor as water does through a tube, and always giving out or absorbing heat till its temperature is that of the conductor, then in passing from hot to cold it would give out heat, and in passing from cold to hot it would absorb heat, and the amount of this heat would depend on the specific heat of the fluid."

Specific Inductive Capacity.—(See *Capacity, Specific Inductive.*)

Specific Resistance.—(See *Resistance, Specific.*)

Specific Resistance of Liquids.—(See *Liquids, Specific Resistance of.*)

Speech, Articulate.——(See *Articulate Speech.*)

Sphygmograph.—An electric apparatus for obtaining a record of the rate and strength of the pulse.

Sphygmophone.—An applicatoin of the *microphone* to the medical examination of the pulse. (See *Microphone.*)

Spiral, Roget's ———A suspended wire spiral conveying a strong electric current, and devised to show the attractions produced by parallel currents flowing in the same direction.

The lower end of the wire spiral dips into a mercury cup. On the passage of the current, the attraction of the neighboring turns of the spiral for each other shortens the length of the spiral sufficiently to draw it out of the mercury and thus break the circuit. When this occurs the weight of the spiral causes it to fall and again re-establish the circuit. A rapid automatic make-and-break is thus established, accompanied by a brilliant spark at the mercury surface due to the extra spark on breaking.

Split Battery.—(See *Battery, Split.*)

Spring-Jack.—A device for readily inserting a loop in a main electric circuit. (See *Board, Multiple Switch.*)

Spring-Jack Cut-Out,—A device similar in general construction to a spring jack, but employed to cut out a circuit.

An insulated plug is thrust between spring contacts, thus breaking the circuit by forcing them apart.

Spurious Resistance.—A false resistance arising from the development of a *counter electro-motive force.* (See *Counter Electro-Motive Force.*)

Standard Candle.—(See *Candle, Standard.*)

Standard Carcel Gas Jet.—(See *Carcel Standard Gas Jet.*)

Standard Cell.—A voltaic cell the electro-motive force of which is constant, and which, therefore, may be used in the measurement of an unknown electro-motive force.

Absolute constancy is impossible to attain, but, if the current of the standard cell is closed but for a short time the electromotive force may be regarded as invariable.

Standard Cell, Clark's ——— —The form of standard cell shown in Fig. 353.

Latimer Clark's Standard Cell, assumes a variety of forms. The H-form is arranged as shown in Fig. 353. The vessel to the left contains at A an amalgam of pure zinc. The other vessel contains at M mercury covered with pure mercurous sulphate. Both vessels are then filled above the level of the cross tube, with a saturated solution of zinc sulphate *Z*, *Z*, to which a few crystals of the same are added. Tightly fitting corks *C*, *C*, prevent loss by evaporation.

The value of this cell in legal volts is $1.438(1 - 0.00077(t - 15° \text{ C.})$ (*Ayrton.*)

The value *t*, is the temperature in degrees of the centigrade scale.

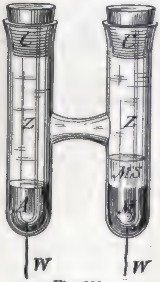


Fig. 353.

Standard Cell, Fleming's ——— —The form of standard cell shown in Fig. 354.

The U tube, Fig. 354, is connected, as shown, by means of taps, with two vessels filled with chemically pure solutions of copper sulphate of Sp. Gr. 1.1 at 15° C., and zinc sulphate of Sp. Gr. 1.4 at 15° C. respectively. To use the cell the zinc rod Zn, connected with a wire passing through a rubber stopper is placed in the left hand branch. The tap A is opened and the entire U-tube is filled with the denser zinc sulphate solution. The tap at C is then opened, and the liquid in the right hand branch above the tap is discharged into the lower vessel, but, from this part only. The tap C is then closed, and the tap B opened, and the lighter copper sulphate allowed to fill the right hand branch above the tap C. The copper rod Cu, fitted to a rubber stopper and con-

nected with a conducting wire, is then placed in the copper solution.

Tubes are provided at L and M, for the reception of the zinc and copper tubes when not in use. The copper tube is prepared for use by freshly electro-plating it with copper. The E. M. F. of this cell is 1.074 volts. If the line of demarcation between the two liquids is not sharp, the arms of the vessels are emptied, and fresh liquid is run in.

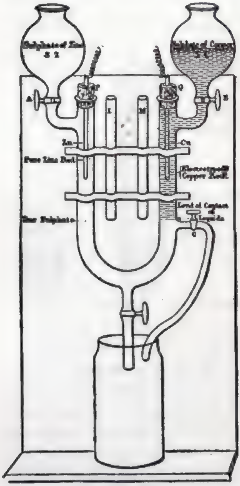


Fig. 354.

Standard Resistance Coil.—(See *Resistance Coil, Standard.*)

State, Allotropic ———(See *Allotropy.*)

State, Nascent —— —(See *Nascent State.*)

State, Passive —— of Iron.—(See *Passive State.*)

State, Permanent —— The condition of the charge of a telegraph wire when the current reaching the distant end has the same strength as at the sending end.

State, Variable —— —The condition of the charge of a telegraph wire while the strength of current is increasing up to the full strength in all parts.

The duration of the variable state is directly as the length of the line and its total resistance. It is increased by leakage, and by the effect of the extra current. (See *Currents, Extra.*)

Static Charge.—(See *Charge, Static.*)

Static Electricity.—A term formerly applied to electricity produced by friction. (Now obsolete.)

The term static electricity is properly employed in the sense of a *static charge* but not as *static electricity,* since that would indicate a particular kind of electricity, and, as is now generally recognized, electricity, from no matter what source it is derived, is one and the same thing.

Statics.—The science which treats of the relations that must exist between the points of application of forces and their direction and intensity, in order that equilibrium may result.

Stay Rods, Telegraphic ——— ————Metallic rods, attached to a telegraph pole, and securely fastened in the ground in order to counteract the effects of a pull or tension on the poles. (See *Poles, Telegraphic.*)

Steel, Qualities of ——— Requisite for Magnetization.—Qualities which must be possessed by steel in order to permit it to permanently retain a considerable magnetization.

For the purposes of magnetization steel should possess the following qualities:

It should be hard, and fine grained. Hard cast steel answers the purpose very well. Scoresby showed that an intimate relation exists between the quality of the iron from which the steel is made, and its ability to take and retain considerable magnetism.

An admixture to steel of about .03 per cent. of tungsten is said to increase its magnetic powers. Cast steel is not generally employed for magnets, wrought steel being generally preferred.

St. Elmo's Fire.—Faintly luminous globes, due to electric brush discharges, sometimes seen on the ends of a ship's masts, or other similar locations.

Step-by-Step or Dial Telegraphy.—A system of telegraphy in which the signals are registered by the movements of a needle over a dial on which the letters of the alphabet, etc., are marked.

Dial telegraphs are employed for communication by those who are unable to readily read the Morse characters.

The annexed instrument, devised by Breguet, was formerly used on some of the railway systems of France.

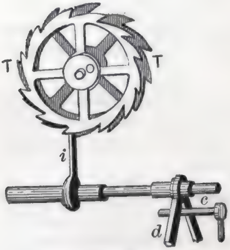


Fig. 355.

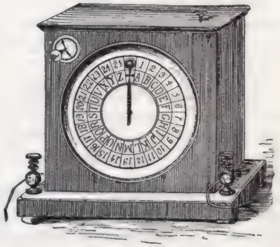


Fig. 356.

A needle advances over a dial in one direction only by a step-by-step movement. The alternate to-and-fro motions of the armature of an electro magnet are employed to impart a step-by-step motion to a peculiarly shaped toothed wheel T, T, Fig. 355, through the action of a horizontal arm *c*, attached thereto, and moving between the two prongs of a fork *d*, vibrating on a horizontal axis to which is attached a vertical pallet *i*.

The receiving instrument is called the *Indicator*, and consists of a needle attached to the axis of this wheel. The needle moves over the face of the dial, shown in the Fig. 356, on which are marked the letters of the alphabet and the numerals.

The sending instrument is called the *Manipulator*. It con-

sists of a device for readily sending over the line the number of successive impulses required to move the needle step-by-step from any letter on the indicator, to which it may be pointing, to the next it is desired to send. The dial, shown in Fig. 357, is marked on its face with the same characters as the indicator. The edge of the wheel is provided with twenty-six notches in which a pin attached to a movable arm engages. This arm is jointed so that it can be placed in any of the notches on the face of the wheel.

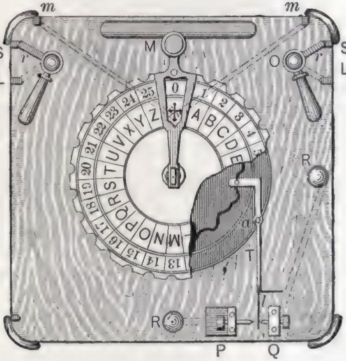


Fig. 357.

Below the dial face, and attached to the same axis as the movable arm, is a wheel provided with undulations consisting of thirteen elevations and thirteen depressions.

A lever T, pivoted at *a*, rests in these undulations at its upper end, and plays between two contact points at P and Q.

If, now, the dials of the indicator and the manipulator both being at *o*, a movement is given to the arm by the handle M,

to any point on the manipulator, there are thus produced the required number of makes and breaks to move the needle of the indicator to the corresponding letter or character.

Step-by-Step Telegraphy.—(See *Telegraphy, Step-by-Step.*)

Stool, Insulating.—A stool, provided with insulating supports of vulcanite or other insulator, employed to afford a ready insulating stand or support. (See *Insulating Stool.*)

Storage Cells, or Accumulators.—Two inert plates of metal, or of metallic oxides, immersed in an electrolyte incapable of acting on them until after an electric current has been passed through the liquid from one plate to the other.

On the passage of an electric current through the electrolyte, its decomposition is effected and the electro positive and electro negative radicals are deposited on the plates, or unite with them, so that on the cessation of the charging current, there remains a voltaic cell capable of generating an electric current.

A storage cell is *charged* by the passage through the liquid from one plate to the other of an electric current, derived from any external source. The *charging current* produces an electrolytic decomposition of the inert liquid between the plates, depositing the *electro positive radicals*, or *kathions*, on the plate *connected* with the negative terminal of the source, and the electro negative radicals, or *anions*, on the plate connected with the positive terminal.

On the cessation of the charging current, and the connection of the charged plates by a conductor outside the liquid a current is produced, which flows through the liquid from the plate covered with the electro positive radical, to that covered with the electro negative radical, or in the *opposite direction to that of the charging current.*

The simplest storage cell is Plantè's cell, which, as originally constructed, consists of two plates of lead immersed in dilute sulphuric acid, $H_2 SO_4$. On the passage of the charg-

ing current, the plates A and B, Fig. 358, dipped in $H_2 SO_4$, are covered respectively with lead peroxide $Pb O_2$, and finely divided, spongy lead. The peroxide is formed on the positive plate, and the metallic lead on the negative plate.

When the charging current ceases to pass, the cell discharges in the opposite direction, viz., from B′ to A′, that is, from the spongy lead plate to the peroxide plate, as shown in Fig. 359.

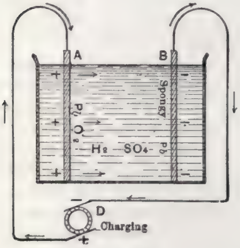


Fig. 358.

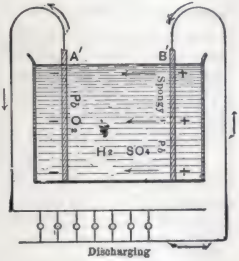


Fig. 359.

As a result of this discharging current the peroxide, $Pb O_2$, on A′, gives up one of its atoms of oxygen to the spongy lead on B′, thus leaving both plates coated with a layer of Pb O, lead monoxide, or litharge. When this change is thoroughly effected, the cell becomes inert, and will furnish no further current until again charged by the passage of a current from some external source.

In order to increase the capacity of the storage cells, and thus prolong the time of their discharge, the coating of lead monoxide thus left on each of the plates, when neutral, is made as great as possible. To effect this, a process called *forming the plates* is employed, which consists in first charging the plates as already described, and then reversing the

direction of the charging current, the currents being sent through the cell in alternately opposite directions, until a considerable depth of the lead plates has been acted on.

It will be noticed that during the action of the *charging* current, the oxygen is transferred from the PbO_2, on one plate, to the $Pb\ O$ on the other plate, thus leaving one Pb, and the other $Pb\ O_2$; and that on *discharging*, one atom of oxygen is transferred from the $Pb\ O_2$, to the Pb, thus leaving both plates covered with $Pb\ O$. In reality this is but the final result of the action, hydrated sulphate of lead, $PbO, H_2\ SO_4$, being formed, and subsequently decomposed.

In order to decrease the time required for forming, accumulators or secondary cells have been constructed, in which metallic plates covered with *red lead* $Pb_3\ O_4$, replace the lead plates in the original Planté cell. On charging, the $Pb_3\ O_4$, is peroxidized at the *anode, i. e.*, converted into $Pb\ O_2$, and deoxidized, and subsequently converted into metallic lead at the *kathode*. Or, in place of the above $Pb_3\ O_4$, red lead was placed on the anode and $Pb\ O$, or *litharge* on the kathode.

Plates of compressed litharge have also been recently used for this purpose. Storage cells so formed have a greater storage capacity per unit weight than those in which a grid is employed.

In all such cases, various irregularities of surface are given to the plates, in order to increase their extent of surface and to afford a means for preventing the separation of the coatings. The metallic form thus provided is known technically as a *grid*.

Unless care is exercised, the plates will *buckle* from the difference in the expansion of the lead and its filling of oxide. This buckling is attended with an increase in the resistance of the cell and the gradual separation of the oxides that cover or fill it.

Storage of Electricity.—A term improperly employed to indicate such a storage of energy as will enable it to directly reproduce electric energy.

A so-called storage battery does not store electricity, any more than the spring of a clock can be said to store time or sound. The spring stores muscular energy, *i. e.*, renders the muscular kinetic energy, potential, which, again becoming kinetic, causes the works of the clock to move and strike.

In the same way in a so-called storage battery, the energy of an electric current is caused to produce electrolytic decompositions of such a nature as to independently produce a current on the removal of the electrolyzing current. (See *Storage Cells.*)

Storms, Electric or Magnetic ——.—(See *Magnetic Storms.*)

Storms, Thunder —— Geographical Distribution of.—The following general facts as to the geographical distribution of thunder storms, show the intimate relation between the frequency of thunder storms and the time and place of the condensation of vapor.

(1) Thunder storms seldom, if ever, occur in the polar regions. This is probably because the rain fall here results from the condensation of the vapor at times and in regions remote from the times and regions in which it was formed.

(2) Thunder storms seldom, if ever, occur in rainless districts owing probably to the absence of the condensation of vapor.

(3) Thunder storms are most frequent and violent in the equatorial regions, where the rain fall results from the condensation of the vapor by the action of ascending currents, conveying the vapor almost immediately after its formation into the upper and colder regions of the atmosphere.

(4) Thunder storms occur in regions beyond the tropics, at those seasons of the year when the rain fall results from the condensation of the vapor shortly after the time of its formation, viz., in the temperate zones in the hotter parts of the year.

Strain.—The deformation of a body under the influence of a *stress.* (See *Stress.*)

Strain, Dielectric —— —(See *Dielectric Strain.*)

Strain, Electro-Magnetic, Optical —— —(See *Optical Strain, Electro-Magnetic.*)

Strain, Electrostatic, Optical —— —(See *Optical Strain, Electrostatic.*)

Strain, Optical —— —(See *Optical Strain.*)

Stratification Tube.—An exhausted glass tube, the residual atmosphere of which displays alternate dark and light striæ, or stratifications, on the passage through it of an induction coil discharge. (See *Luminous Effects of Discharge.*)

Stray Power.—A term used to indicate the power lost in driving a dynamo-electric machine, through friction, air churning or currents, and eddy currents.

Strength of Current.—(See *Current, Strength.*)

Strength of Magnetism.—(See *Magnetism, Intensity of.*)

Stress.—The pressure or pull producing a deformation or strain. (See *Strain.*)

Stress, Electrostatic, or Electro-Magnetic —— —(See *Optical Strain.*)

Striæ, Electric —— —(See *Stratification Tubes.*)

Struts for Telegraphic Poles.—Inclined wooden or iron poles, applied to telegraph poles in order to remove the thrust or pressure acting on them. (See *Poles, Telegraphic.*)

Sturgeon's Wheel.—(See *Accumulator. Barlow's Wheel.*)

Submarine Boats.—(See *Boats, Submarine.*)

Submarine Cables.—(See *Cables, Submarine.*)

Submarine Mines.—(See *Mines, Submarine.*)

Submarine Telegraphy —— —(See *Telegraphy, Systems of.*)

Substance, Ferro-Magnetic.—(See *Ferro-Magnetic Substance.*

Subway, Electric —— —An accessible underground way or passage provided for the reception of electric wires or cables.

Underground electric conductors like all electric conductors are liable to faults, crosses, etc., etc. Unless they are readily accessible very serious loss and damage may occur before the fault is located and corrected.

Sun Spots.—Dark spots, varying in number and position, which appear on the face of the sun, and are believed to be caused by huge vortex motions in the masses of glowing gas that surround the sun's body.

Sun spots occur in greater number at intervals of about every eleven years.

Their occurrence is generally attended with unusual terrestrial magnetic variations. (See *Magnetic Storms.*)

Sunstroke, Electric —— or Electric Prostration, or Insolation.—Physiological effects, similar to those produced by exposure to the sun, experienced by those exposed for a long while to the intense light and heat of the voltaic arc.

These effects were first noticed by Desprez in his classic experiments on the fusion or volatilization of carbon. The eyes are irritated and the skin burned as by the sun. In some cases it is claimed that the effects of sunstroke, or excessive production of heat, as in true *insolation*, are produced. In the more modern application of electricity to electric furnaces, these same effects have been noticed in an intensified degree.

From some recent investigations it would appear that these effects are to be ascribed to the light rather than to the heat.

The symptoms are as follows: Pain in the throat, face and temples, followed by a coppery red color of the skin, irritation and watering of the eyes, when the symptoms disappear. The skin peels off in about five days.

Surfaces, Equipotential Electrostatic ——— —(See *Equipotential Surfaces, Electrostatic.*)

Surfaces, Equipotential Magnetic ——— —(See *Equipotential Surfaces, Magnetic.*)

Susceptibility, Magnetic ——————— —A term expressing the ratio existing between the intensity of the induced and the inducing magnetism.

The magnetic susceptibility of a bar of iron is equal to the intensity of the induced magnetism divided by the strength the inducing field.

Suspension, Bi-Filar ——— —The suspension of a needle by two parallel wires or fibres, as distinguished from a suspension by a single wire or fibre. (See *Bi-Filar Suspension.*)

Suspension, Combined Fibre and Spring ——— —The suspension of a needle by the combined use of a spiral spring and a single fibre.

In this form of suspension the spring is introduced between the fibre and the needle. It is valuable for marine galvanometers, and other apparatus exposed to tilting or rolling motions, because it permits the instrument to be tilted through several degrees without causing any considerable variation in the deflections produced by the current or the charge.

Suspension, Fibre ——— —Suspension of a needle by means of a fibre of unspun silk or other material.

A fibre suspension generally means a single fibre or thread. It may, however, be applied to a bi-filar suspension. (See *Suspension, Bi-Filar.*)

A fibre suspension is to be preferred to a *pivot* suspension, since it introduces far less friction. It has, however, the disadvantage of necessitating levelling screws.

Suspension, Knife Edge ———— —The suspension

of a needle on knife edges that are supported on steel or agate planes.

A suspension of this kind is used in the dipping needle, since it permits of freedom of motion in a single vertical plane only.

Suspension, Pivot ——————Suspension of a needle by means of a jewelled cup and a metallic pivot.

The jewelled cup is placed above the centre of gravity of the needle, and is supported on a steel point. As a rule compass needles have this variety of support.

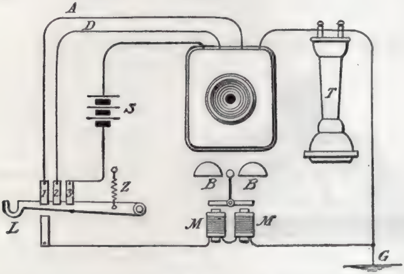


Fig. 360.

Switch, Automatic Telephone——— — A device for transferring the connection of the main line from the *call bell* to the telephone circuit.

In most telephone circuits, as now arranged, the automatic switch, beside transfering the main line from the call bell to the telephone circuit, closes the local battery circuit of the transmitter on the removal of the telephone from its supporting hook.

The means whereby this is accomplished are shown in Fig. 360. On the removal of the telephone from the hook L, the lever is pulled upwards by the spring Z, thus closing the

contacts 1, 2 and 3, by which the local battery S is closed in the circuit of the transmitter, the telephone disconnected from the circuit of the *call bell* M, B, and connected with the circuit of the transmitter. On replacing the telephone on the hook L its weight depresses the lever, breaking connection with 1, 2 and 3, and establishing connection with the call circuit.

Switch Board.—(See *Board, Switch.*)

Switch, Double Pole ——— — A switch that makes or breaks contact with both poles of the circuit in which it is placed.

Double-pole switches are used in most systems of incandescent lighting in order to insure the thorough separation of the circuit from the main conductor or leads when cut out.

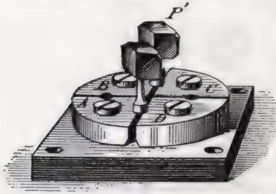


Fig. 361.

Switch, Reversing ——— — A switch for reversing the direction of the battery current through a galvanometer.

A simple reversing switch consists of four insulated brass segments mounted on a plate of ebonite and furnished with openings between them for plug connections. The battery terminals are connected to two diagonally opposite segments as B and D, Fig. 361, and the leading wires of the galvanometer, or other instrument, to the other segments as C and A. If now the plugs are placed between B and C, and A and D, the battery current flows in one direction. If, however, the plugs are placed between A and B, and C and D, the battery current will flow in the opposite direction.

The battery current is cut off if one plug is removed. In practice, however, it is perferable to remove both plugs, so as to avoid any current from want of sufficient insulation.

Sympathetic Vibrations.—Vibrations set up in bodies by sound waves of exactly the same wave length as those produced by the vibrating body.

The pitch or tone of the note produced by the body set into sympathetic vibration, is exactly the same as the pitch or tone of the exciting waves or vibrations.

Synchronism.—The simultaneous occurrence of any wo events.

A rotating cylinder, or the movement of one index or trailing arm, is brought into synchronism with another rotating cylinder or another index or trailing arm, not only when the two are moving with merely the same speed, but when in addition they *are simultaneously moving over similar portions of their respective paths.*

In the Breguet *Step-by-Step* or *Dial Telegraph* (See *Step-by-Step or Dial Telegraph*), the movements of the needle on the Indicator, are synchronized with the movements of the needle on the *Manipulator.* In systems of *Fac-Simile Telegraphy,* the movements of the transmitting apparatus are synchronized with that of the receiving apparatus. In Delany's *Synchronous Multiplex Telegraph System,* the trailing-arm that moves over a circular table of contacts at the transmitting end, is accurately synchronized with a similar trailing-arm moving over a similar table at the receiving end.

Delany, who was the first to obtain rigorous synchronism at the two ends of a telegraphic line hundreds of miles in length, accomplises this by the use of La Cour's phonic wheel, through the agency of correcting electric impulses, automatically sent in either direction over the main line, when one trailing arm gets a short distance in advance or back of the other.

Synchronous Multiplex Telegraphy.—(See *Telegraphy, Synchronous Multiplex.*)

System, Astatic ——— —(See *Astatic System.*)

System, Block —— of Railway Telegraphy.—(See *Block System for Railways.*)

System, Centimetre-Gramme-Second —— of Measurement.—(See *Centimetre-Gramme-Second System of Measurement.*)

Systems of Distribution by Alternating Currents.—System of electric distribution by the use of alternating currents.

Such a system embraces,

(1) An Alternating-Current Dynamo-Electric Machine.

(2) A Conductor or Line Wire having a metallic circuit.

(3) A number of Converters whose primary coils are placed in the circuit of the line wire.

(4) A number of Electro Receptive Devices placed in the circuit of the secondary coil of the converter.—(See *Converter or Transformer.*)

Systems of Distribution by Constant Currents.—Systems for the distribution of electricity by means of constant currents.

Distribution by means of constant currents may be effected in a number of ways; the most important are:

(1) Distribution with *Constant Current* or *Series Distribution.*

(2) Distribution with *Constant Potential* or *Multiple Distribution.*

In a System of *Series Distribution*, the electro receptive devices are placed in the main line in series, so that the electric current passes successively through each of them. In such a system each device added increases the total resistance of the circuit.

In order therefore to maintain the current strength constant, independent of the number of devices added, the electromotive force of the source must increase with each electro-receptive device added, and decrease with each electro-recep-

tive device taken out. If the number of electro-receptive devices be great, such a circuit is necessarily characterized by a comparatively high electro-motive force.

Since the current passes successively through all the electro-receptive devices, an automatic safety device is necessary in order to automatically provide a short circuit of comparatively low resistance past the faulty device, and thus prevent a single faulty device from invalidating the action of all other devices in the circuit.

Arc lamps are usually connected to the line circuit in series.

In a System of *Multiple Distribution*, the electro-receptive devices are connected with the main line or leads in *multiple-arc*, or *parallel*, so that each device added *decreases the resistance of the circuit*. In order, therefore, to maintain a proper current through the electro-receptive devices, the mains must be kept at a nearly constant difference of potential. The electro-receptive devices employed in such a system of distribution are generally of high electric resistance, so that the introduction or removal of a few of the electro-receptive devices will not materially alter the resistance of the whole circuit, and will not, therefore, materially affect the remaining lights.

In this system automatic safety devices, operating by the fusion of a readily melted alloy or metal, are provided for the purpose of preventing too powerful currents from passing through any branch connected with the *main conductors* or *leads*.—(See *Plug, Fusible.*)

Incandescent lamps are generally connected with the main conductors or leads in *parallel* or *multiple-arc*.

Distribution of incandescent lamps by series connections is sometimes employed. Such lamps are usually of comparatively low resistance, and are provided each with an automatic cut-out, which establishes a short circuit past the lamp on its failure to properly operate.

During the passage of an electric current through any series distribution circuit, energy is expended in different portions of

the circuit, in the proportion of the resistance of these parts. In any system, economy of distribution necessitates that the energy expended in the electro-receptive devices must bear as large a proportion as practicable to the energy expended in the source and leads. In series distribution, this can readily be accomplished even if the resistance of the leads is comparatively high, since the total resistance of the circuit increases with every electro-receptive device added. Comparatively thin wires can therefore be employed, for a very considerable extent of territory covered, without considerable loss.

In systems of multiple distribution, however, this is impossible; for, since every electro-receptive device added decreases the total resistance of the circuit, unless the resistance of the leads is correspondingly decreased the economy becomes smaller, unless the resistance of the leads was originally so low as to be inappreciable as compared with the change of resistance.

In systems of distribution by alternating currents, this is avoided by passing a current of but small strength and considerable difference of potential over a line connecting distant stations, and converting this current into a current of large strength and small difference of potential where it is required for use.

Tachograph.—An apparatus for recording the number of revolutions of a shaft or machine per minute.

Tachometer, or Speed Indicator.—An apparatus for determining the number of revolutions of a shaft or machine per minute.

Various forms of apparatus are employed for this purpose.

Tachyphore.—A term proposed by Wurtz for a system of electric transportation, in which a carriage of magnetic material is propelled by the sucking action of solenoids placed along the track and energized in succession during the passage of the car.

Tangent.—One of the trigonometrical functions. (See (*Trigonometry.*)

Tangent Galvanometer.—A galvanometer in which the current strength passing through the deflecting coil is proportional to the tangent of the angle of deflection it produces in the needle. (See *Galvanometer*, *Tangent.*)

Tangent Scale.—A scale designed for use with a galvanometer, on which the values of the tangents are marked, instead of equal degrees as ordinarily, thus avoiding the necessity of finding from tables the tangents corresponding to the degrees.

Such a scale may be constructed as follows: Draw the *tangent* B T, to the circle, Fig. 362, and lay off on it any number of equal divisions or parts as, for example, the thirty shown in the annexed figure. Connect these parts with the centre C, of the circle. The arc of the circle will thus be

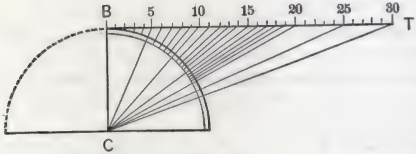


Fig. 362.

divided into parts proportional to the value of the tangents of the angles. These parts are more nearly equal the nearer they are to B, and grow smaller and smaller the further they are from B. In tangent galvanometers, it is therefore very difficult to accurately determine the current strength when the deflections of the needle are very large.

Tape, Insulating ——— —A ribbon of flexible material impregnated with kerite, okonite, rubber, or suitable insulating material employed for insulating wires or electric conductors at joints, or other exposed places.

Sometimes the tape is formed entirely of the above named insulating materials.

Tapper, Double —— Key.—The key used in systems of needle telegraphy to send electric impulses through the line in alternately opposite directions as desired. (See *Telegraphy, Single Needle.*)

Target, Electric —— —A target in which the point struck by the ball is automatically registered by electric devices.

A variety of targets have been devised; generally, however, the target is divided into a number of separate sections, provided with circuits of wires on the making or breaking of any of which, by the impact of the ball, the section struck is automatically indicated on an electric *annunciator.*

Teazer, Electric Current —— — A name employed by Brush for a field magnet shunt circuit around the external circuit of his dynamo-electric plating machine. (See *Dynamo-Electric Machine, Shunt.*)

Tel-Autograph.—A telegraphic system for the fac-simile reproduction of handwriting.

Tele-Barometer, Electric —— —An electric recording barometer for indicating and recording barometric or other pressure at a distance.

Telegraph, Electric ———— — An apparatus for the electric transmission of signals between stations connected by electric conductors.

Various systems of telegraphy are in common use, all of which, however, consist of various forms of the following apparatus, viz.:

(1) *Transmitting Apparatus,* by means of which electrical impulses are sent into the line.

(2) *Receiving Apparatus,* by means of which the electric impulses are caused to produce visible or audible signals, which may, or may not, be permanently recorded.

(3) *A Conducting* or *Line Wire* connecting the two stations.

(4) *Main and Local Batteries* for producing the currents employed in the transmission and reception of the signals.

(5) *Various Relays and Repeaters*, employed on long lines, in order to permit additional local batteries to be used to carry the electric impulses over longer lines than could otherwise be employed.

Telegraphic Code.—(See *Alphabet, Telegraphic.*)

Telegraphic Embosser.—(See *Embosser, Telegraphic.*)

Telegraphic Joints.—(See *Joints, Telegraphic.*)

Telegraphic Needle.—(See *Needle, Telegraphic.*)

Telegraphic Switch Board.—A device employed at a telegraph station by means of which any one of a number of telegraph instruments, in use at that station, may be placed in, or removed from, any line connected with the station.

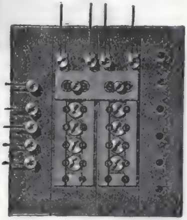


Fig. 363.

In the switch board shown in Fig. 363, the upper left hand binding post is connected to earth; the four remaining binding posts are connected to two separate instruments. The second and third from the top, to one instrument, and the fourth and fifth, to another instrument. The four posts at the top of the figure are connected to two lines running east and west.

Various connections are made by the insertion of plug keys in the various openings.

Telegraphy, American or Morse System of——

—In the Morse system, as now generally employed in America, the transmitting apparatus consists essentially of a *telegraphic key*, by means of which the main line circuit can be readily made or broken in accordance with the dots and dashes of the Morse *Alphabet.* (See *Alphabet, Morse.*)

A metallic lever A, Fig. 364, is supported on a pivot at G, between two set screws D, D, so as to have a slight movement in a vertical plane. This motion is limited in one direction by a stop at C, called the *anvil* or *front contact*, and in the other direction by a set screw F, which constitutes its *back stop*. The front stop C, is provided with a platinum contact or stud, which may be brought into contact with, or separated from, a similar stud placed directly opposite it. These contacts are connected to the ends of the circuit, so that

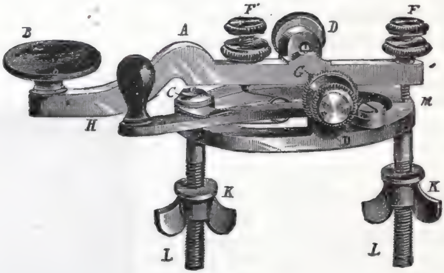


Fig. 364.

on the movements of the key, by the hand of the operator placed on the insulated head B, the line is closed and broken in accordance with the dots and dashes of the Morse alphabet. A spring, the pressure of which is regulated by the screw F', is provided for the upward movement of the key. A switch H, is provided for closing the line when the key is not in use, since the system as generally used in the United States the line is operated on *closed circuit*.

In the Morse system each station is provided with a key, relay, sounder or register, and a local battery. The closed circuit, connecting one station with another, being broken by the opening of the switch H, on the working of the key, so as

to open and close its contacts, the armature of the relay opens or closes the circuit of the local battery and operates the *sounder* or *registering apparatus* connected therewith. (See *Sounder, Telegraphic. Registering Apparatus, Telegraphic.*)

Telegraphy, Automatic ——— —Apparatus by means of which a telegraphic message is automatically transmitted by the motion of a previously perforated fillet of paper containing perforations of the shape and order required to form the message to be transmitted.

The paper passes between two terminals of the main line, the circuit of which is completed when the terminals come into contact at the perforated parts, and is broken when separated by the paper.

The advantages of the automatic telegraph arise from the fact that since the paper fillets can be prepared beforehand, great speed is attained by their aid. In the automatic telegraph some form of registering apparatus is employed.

Type-printing telegraphs are often used for registering apparatus, in which case the impulses required for the transmission of the different letters are automatically sent into the line by the depression of corresponding keys on a suitably arranged key-board.

Telegraphy, Chemical ——— —(See *Recorder, Bain's Chemical.*)

Telegraphy, Dial ——— — (See *Telegraph, Step-by-Step.*)

Telegraphy, Double Needle ——— — A system of needle telegraphy in which two separate and independently operated needles are employed.

This system differs from the single needle system only in the fact that two needles, entirely independent of each other are mounted side by side, on the same dial, so as to permit their simultaneous operation by the right and left hand of the operator. Each needle has therefore a separate wire. The

increase in speed of signaling thus obtained is not, however, sufficiently great to balance the increased expense of construction. Single needle instruments, therefore, are preferred to those with two needles.

Telegraphy, Diplex ——— — A method of simultaneously sending two messages in the *same* direction over a single wire.

Telegraphy, Duplex ——— — —Devices whereby two telegraphic messages can be simultaneously transmitted over a single wire in *opposite* directions.

Various duplex telegraphs have been devised.

The *Bridge Duplex* is shown in Fig. 365. The receiving relay is placed in the cross wire of a *Wheatstone's balance.* (See *Balance, Wheastone's Electric.*)

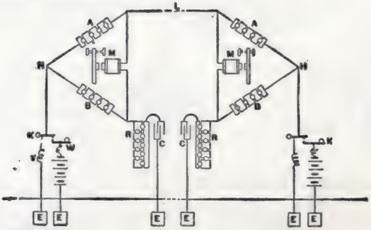


Fig. 365.

When the ends of this cross wire are at the same potential, which will occur when the resistances in the four arms are proportionally equal, no current passes.

The battery is connected through the transmitter K, which is arranged so that the battery contact is made before the connection of the line to earth is broken, to H, where the circuits branch to form the arms of the bridge. Adjustable resistances A, B, are placed in the two arms of the bridge. The line wire L, connected as shown, forms the third arm and a

rheostat or other adjustable resistance R, connected to a condenser C, as shown, forms the fourth arm. (See *Rheostat.*) The relay M, is placed in the cross wire of the bridge thus formed. Small resistances V and W, are placed in the circuit of the battery to prevent injurious short-circuiting.

A similar disposition of apparatus is provided at the other end of the line. If, now, the four resistances at one end are suitably adjusted, the relay will not respond to the outgoing current; but, since an earth circuit is employed, it will respond to the incoming current. The relay at either end, therefore, will only respond to signals from the other end. The operator may thus signal the distant station while, at the same time, his relay, not being affected by his sending, is in readiness to receive signals from the other end.

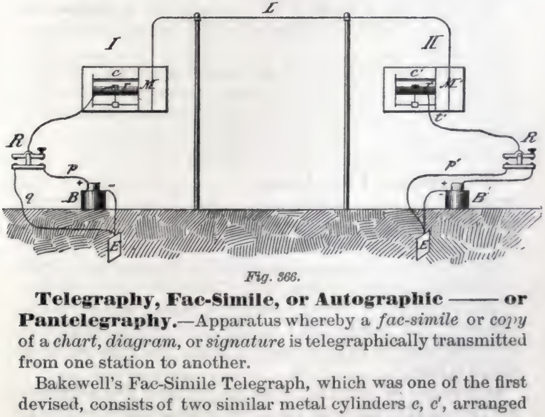


Fig. 366.

Telegraphy, Fac-Simile, or Autographic —— or Pantelegraphy.—Apparatus whereby a *fac-simile* or *copy* of a *chart, diagram,* or *signature* is telegraphically transmitted from one station to another.

Bakewell's Fac-Simile Telegraph, which was one of the first devised, consists of two similar metal cylinders *c, c'*, arranged at the two ends of a telegraph line L, at M and M', as shown in Fig. 366. These cylinders are synchronously rotated and

provided with metallic arms or tracers r, r', placed on a horizontal screw in the line circuit and moved laterally, over the surface of the cylinder on its rotation

At the transmitting station the chart, writing, or other design is traced with varnish, or other non-conducting liquid, on the surface of the metallic cylinder, as at M, and a sheet of chemically prepared paper, similar to that employed in the Bain Chemical System is placed on the surface of the receiving cylinder at M′. (See *Recorder, Bain's Chemical.*)

The two cylinders being synchronously rotated, the metallic tracer breaks the circuit in which it is placed when it moves over the non-conducting lines on the cylinder, and thus causes corresponding breaks in the otherwise continuous blue spiral line traced on the paper-covered surface of M′.

The telegraph keys at R, R′, are used for the purposes of ordinary telegraphic communication before or after the record is transmitted.

Caselli's Pan-Telegraph is an improvement on Bakewell's Copying Telegraph. Better methods are employed for maintaining the synchronism between the transmitting and receiving instruments, for which purpose a pendulum, vibrating between two electro magnets, is employed.

Telegraphy, Fire Alarm ——— —A system of telegraphy by means of which alarms can be sent to a central station, or to the fire engine houses in the district, from call boxes placed in the line.

The alarms are generally sounded by an apparatus similar to a district call, so that the pulling back of a lever rotates a wheel, by means of which a series of makes and breaks are produced, the number and sequence of which, enable the receiving stations to locate the particular box from which the signal is sent.

In the case of some buildings, the alarms are automatic, and either call for help from the central office, or for the watchman in the building, or else turn on a series of water

faucets or jets, in order to extinguish the fire. In these cases *thermostats* are used. (See *Thermostats.*)

Telegraphy, Gray's Harmonic Multiple —— —— ———— ———— —A system for the simultaneous transmission of a number of separate and distinct musical notes, over a single wire, which separate tones are utilized for the simultaneous transmission of an equal number of telegraphic messages.

The separate tones are thrown into the lines by means of *tuning forks* automatically vibrated by electro-magnets. These forks interrupt the circuit of batteries connected with the main line at the transmitting end of the line. The composite tone thus formed, is separated into its component tones by receiving electro-magnets called *Harmonic Receivers*, the armature of each of which consist of a steel ribbon or plate tuned to one of the separate notes sent into the line. As the complex or undulatory current passes through the coils of each harmonic receiver, that note only affects the particular armature that vibrates in unison with its ribbon or reed. The operator, therefore, at this receiver is in communication only with the operator at the key of the circuit that is sending this particular note into the line. The same is true of the other receivers.

The Morse alphabet is used in this system, the dots and dashes being received as musical tones. In practice it was found that there was no difficulty in each operator recognizing the particular sound of his own instrument in receiving, although many instruments were in the same room.

Telegraphy, Induction ———— —A system for telegraphing by induction between moving trains and fixed stations on a railroad, by means of impulses transmitted by induction between the car and a wire parallel with the track.

In such a system, conducting wires directly connecting the stations and the moving trains are thus dispensed with, and

the signals are received by means of induction effects produced between the moving train and the fixed station.

Two systems of inductive telegraphy are in actual use, viz.:

(1) The *Static Induction* System of W. W. Smith and Edison, and

(2) The *Current* or *Dynamic Induction* System of Willoughby Smith and Lucius J. Phelps.

In the System of Static Induction, one of the condensing surfaces which receives or produces the charge, consists oı a wire placed on the road so as to come as near the top of the cars of the moving train as possible. The other condensing surface is composed of the metal roofs of the moving cars. Each condensing surface is connected to suitable instruments and batteries, and to the earth; the line wire at the fixed station being connected to earth through a ground plate, and the metal roof of the cars to earth through the wheels and track.

Under these circumstances variations in the charge of either of the condensing surfaces produce inductive impulses that are received by the other surface as telegraphic signals. The Morse alphabet is employed, but in place of the ordinary receiver or sounder, a telephone is used.

In the System of Current Induction, the line wire is placed near the track, so as to be parallel with a coil of insulated wire placed on the side of the car and which receives the inductive impulses. The coil of wire on the train is connected with instruments and batteries, and forms a metallic circuit. The line wire is also connected with suitable batteries and receiving and transmitting instruments.

An induction coil is generally employed since the greater and more rapidly varying difference of potential of its secondary wire renders it better suited for producing effects of induction. A telephone is employed as a receiver, as in the system of static induction. The metallic car roof and the lower truss rods have been successfully used as the primary and secondary conductors of the induction coil.

The automatic make and break used for operating the induction coil, causes the Morse characters employed in this system to be received in the receiving telephone as shrill buzzing sounds.

The receiving telephones used on the trains have a resistance of about 1,000 ohms.

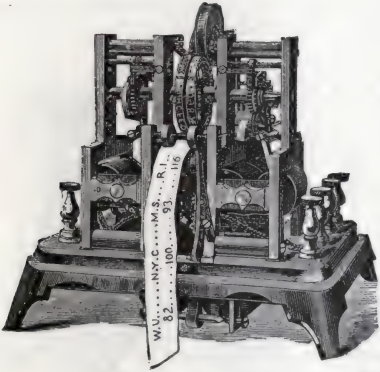


Fig. 367.

Telegraphy, Multiplex ———— —A system of telegraphy for the simultaneous transmission of more than four separate messages over a single wire. (See *Telegraph, Synchronous, Multiplex.*)

Telegraphy, Printing ———— —A system of telegraphy in which the messages received are printed on a paper fillet.

In Callahan's Printing Telegraph, two type wheels are

employed, one of which carries letter type and the other numerals on its circumference. These *printing wheels* are placed alongside of each other, as shown in Fig. 367, but on separate and independent axes.

The type wheels are moved by a *step-by-step* device. When the proper letter or numeral is reached at the receiving end, the printing wheel is stopped, and a paper fillet is pressed against its surface. The printing wheel is kept covered with ink by means of an inked roller.

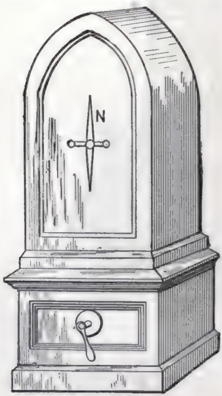


Fig. 368.

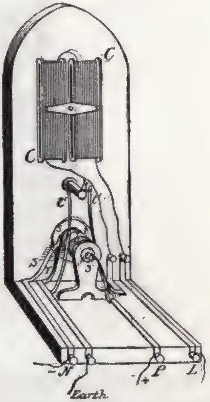


Fig. 369.

The transmitting instrument is similar in its operation to the Breguet *Manipulator*. Separate transmitters are used for each of the wires. (See *Telegraphy, Step-by-Step*.)

Telegraphy, Quadruplex ———— —A system for the simultaneous telegraphic transmission of four messages over a single wire.

There are various systems of quadruplex telegraphy. For the details of their operation the student is referred to standard books on telegraphy.

Telegraphy, Single Needle ————— —A system of telegraphy by means of which the signals transmitted are received by observing the movements of a vertical needle over a dial.

Movements of the top of the needle to the right of the observer represent the dashes, and movements to the left, the dots of the Morse alphabet.

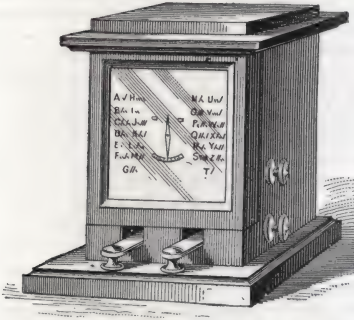


Fig. 370.

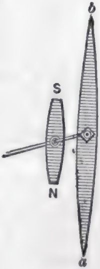


Fig. 371.

The single needle apparatus of Wheatstone and Cooke's system is shown in Figs. 368 and 369. Fig. 368, shows the external appearance, and Fig. 369, the internal arrangements as seen from the back. An astatic needle is placed inside two coils of insulated wire C C. Only one of these needles N, is visible on the face of the receiving instrument. The current from the line enters at L, passes through the coil C C, and leaves at N.

The movements of the needle to the right or the left are obtained by changing the direction of the current in the coils C C. This is effected by working the handle when sending, and thus moving the commutator at S, S, and bringing the contact springs resting thereon into different contacts.

In the more modern form of Single Needle Instrument, shown in Fig. 370, a single magnetic needle N S, Fig. 371, only is placed in the coil.

This needle is rigidly attached to a light needle *a*, *b*, used only as a pointer, and is alone visible in the front of the figure on the left. The relative disposition of these needles is shown in the drawing on the right.

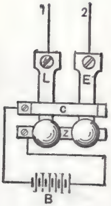


Fig. 372

The reversals of the current, required to deflect the needle to the right or left, are obtained by means of a *double key* or *tapper*, shown in Fig. 372.

The levers L and E, are connected respectively to line and earth, and, when not in use, rest against C, connected with the positive side of the battery; but when depressed connect with Z, attached to the negative side of the battery. The depression of L, therefore, sends a negative current into the line and deflects the needle, say, to the left, while the depression of E sends a positive current into the line and deflects the needle to the right. The terms *positive* and *negative currents* are used in telegraphy to indicate currents whose *direction* is positive or negative.

Telegraphy, Speaking ———— —A system for the telegraphic transmission of articulate speech. (See *Telephones.*)

Telegraphy, Step-by-Step ———— — A system of telegraphy in which the needle of a dial, or the type wheel of a printing telegraph, is moved step-by-step by electric impulses sent over the line. (See *Telegraphy, Needle* or *Dial.*)

Telegraphy, Sub-Marine ——— —A system of telegraphy in which the line wire consists of a sub-marine cable.

In long sub-marine cables, in order to avoid *retardation* from the self-induction of the current, and the *static charge* arising from the cable acting as a condenser, very small currents are used. To detect these a very sensitive receiving instrument, such as the *mirror galvanometer*, or the *siphon recorder*, is employed. (See *Galvanometer, Mirror. Recorder, Siphon.*)

According to Culley, the retardation in the case of one of the sub-marine cables between Newfoundland and Ireland, amounts to *two-tenths of a second* before a signal sent from one end produces any appreciable effect at the other end, while *three seconds* are required for the current through the cable to gain its full strength.

Telegraphy, Synchronous-Multiplex, ——— Delany's System.—A system devised by Delany for the simultaneous telegraphic transmission of a number of messages either all in the same direction, or part in one direction and the remainder in the opposite direction.

The Delany System embraces the following parts :

(1) A circular table of alternately insulated and grounded contacts at either end of a telegraphic line.

(2) A synchronized rotating arm or trailing contact, at each end of the line, driven by a *phonic wheel*, and maintained in synchronous rotation by means of electric impulses automatically sent out over the main line in either direction, on the failure of the wheel at either end to rotate synchronously with that at the other end.

(3) Transmitting and receiving instruments connecting similar contacts at each end of the main line, and forming practically separate and independent lines for the simultaneous transmission of dispatches over the main line in either direction.

The main line is simultaneously connected at both of its ends to corresponding operating instruments, and transferred from one set of instruments to another so rapidly that the operators, either sending or receiving, cannot realize that the line has been disconnected from their instruments and given to others, because each of them will always have the line ready for use, even at the highest rate of manipulation, and will, therefore, to all practical intents and purposes, have at his disposal a private wire between himself and the operator with whom he is in communication.

Therefore, although more than one operator may be spoken of as simultaneously using the line at any given time, yet in point of fact no two operators are in reality absolutely using it at the same time; but they follow one another at such short intervals, and the line is taken from one operator and transferred to another so rapidly that none of them can at any time tell but that he has the line alone, and that therefore it is practically open for the use of every operator just as if he alone had control of it.

There will, therefore, be established, by the use of a single line, as many private and separate lines as there are transferences of the line from the time it is taken from the first operator, and again given back to him.

This system has been extended to as many as seventy-two distinct and separate printing circuits, maintained and operated on a single connecting line wire.

Fig. 373, shows the apparatus at each end of the line, at the stations X and Y. The apparatus at each end is substantially identical. A steel fork a, at each station, is automatically and continuously vibrated by the action of the local battery L B, and the electro-magnet A, called the *vibrator magnet*.

Platinum contacts x, x^1, placed on the inner faces of the tines of the fork, make and break contact with delicate contact springs y, y^1.

The fork being mechanically started into a vibratory mo-

tion, will automatically make and break its local circuit, and thus send impulses into the fork-magnet A, that will continuously maintain the vibrations of the fork, in a well-known manner.

The making and breaking of the contacts x and y, consequent on the fork's vibration, opens and closes a circuit of another local battery called the motor circuit, in which is placed an electro-magnet D, the function of which is to maintain the continuous rotation of the transmission apparatus C.

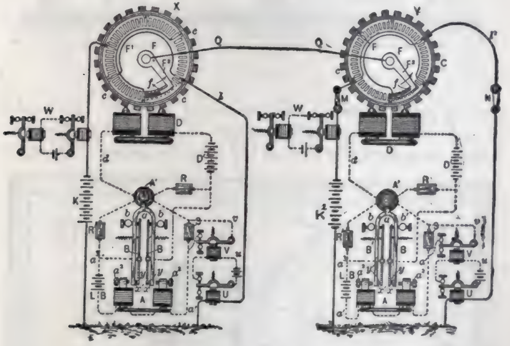


Fig. 373.

The continuous vibration of the fork makes and breaks the contacts at x and y, and thereby makes and breaks the motor circuit. The alternate magnetizations and demagnetizations of the cores of the motor-magnet D cause the rotation of the transmission apparatus C.

The motor-magnet and transmission wheel or disc C, provided with projections c, c, is the invention of Paul La Cour, and is styled by him a ' Phonic Wheel."

The transmission apparatus is illustrated in detail in Figs. 374 and 375, and is an exact counterpart of the receiving apparatus at the other end of the line. A base plate E, provided with

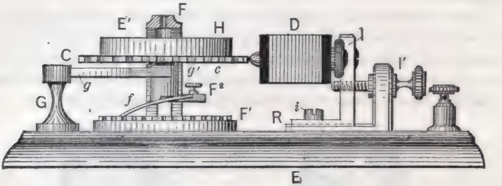


Fig. 374.

binding posts, carries a vertical rotary shaft F. A circular table F¹, is provided with a series of insulated contacts arranged symmetrically around the axis of rotation of the shaft.

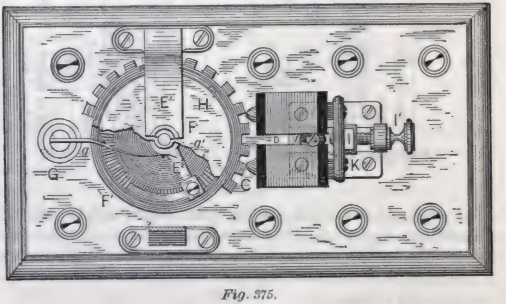


Fig. 375.

A radial arm F², connected with the shaft F, carries at its outer extremity a trailing contact finger *f*. As the disc C is rotated by the electro-magnet D, the trailing contact *f*,

sweeps around the circular table F^1, and is brought successively into contact with the insulated contact-pieces placed on the upper face of the table F^1.

The main line Q. Q, has one of its ends connected with the trailing finger *f*. As the shaft F, rotates, the line is therefore brought into successive electrical connection with the series of insulated contacts in the upper face of the table F^1.

Any suitable number of insulated contacts may be placed on the circular table F^1; sixty are shown in Fig. 376 In practice these contacts are connected in accordance with the number of circuits which it is desired to simultaneously maintain on the same wire. In the special case shown in the figure referred to above, it is arranged so that four separate circuits shall be established on the same line wire. The sixty contacts are placed in six independent series, numbered from 1 to 10, consecutively. In the arrangement here shown two of the contact pieces in each series of ten are connected in the same circuit, and as there are six series, each of the circuits so connected will have twelve contacts for each rotation of the disc, and twelve electrical impulses, as will be afterwards described.

The detailed mechanism by means of which the separate and independent circuits so obtained are utilized for the transmission and reception of messages is shown in Fig. 376. R, R^1, R^2 and R^3 are polarized relays; S, S^1, S^2 and S^3 are ordinary Morse sounders, although in the practice of this invention some improvement has been introduced in connection with the receiving instruments. The connections with the main and the local batteries M B and L B, are clearly shown in the figure.

It will be noticed that the relay R is connected with the wire r, and with the contacts 1 and 5; R^1, is connected by r^1, with the contacts 2 and 6; R^2, by the wire r^2, with the contacts 3 and 7; and R^3, by the wire r^3, with the contacts 4 and 8 Similar instruments and circuits are placed at each end of the line.

Without further describing the operation of the instruments shown in the figure, it need only now be borne in mind that the corresponding relays at the distant stations are connected with the correspondingly numbered contacts When, therefore, the trailing contact finger at each station simultaneously touches the contacts bearing the same number, the corre-

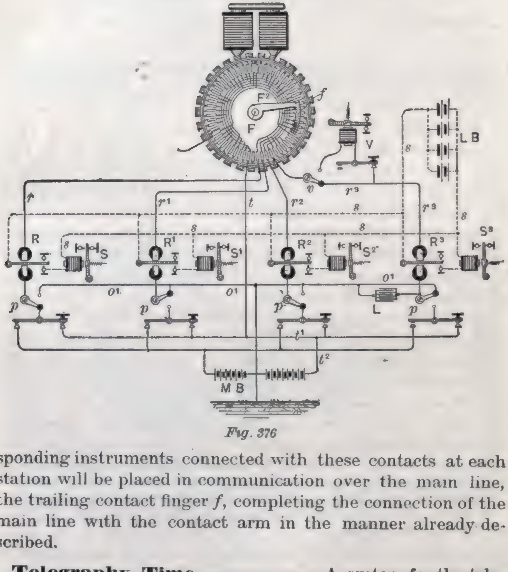


Fig. 376

sponding instruments connected with these contacts at each station will be placed in communication over the main line, the trailing contact finger *f*, completing the connection of the main line with the contact arm in the manner already described.

Telegraphy, Time ———— —A system for the telegraphic transmission of time.

A system of time-telegraphy includes a *master* clock, the movements of whose pendulum automatically transmit a number of electric impulses to a number of *secondary clocks* and thus moves them; or self winding clocks are employed, which are corrected daily by an impulse sent over the line from a master clock.—(See *Clocks, Electric.*)

Tele-Manometer, Electric ——— —A gauge for electrically indicating and recording pressure at a distance.

Fig. 381.

The tele-manometer includes a pressure gauge furnished with electric contacts operated by the movements of the needle of the steam gauge for instance, and indicating and recording apparatus. An alarm bell is provided to call attention to any rise of the pressure above, or its fall below the given or predetermined limits for which the hands have been set.

Telemeter.—An apparatus for electrically indicating and recording at a distance, the pressure on a gauge, the reading of a thermometer, or the indications of similar instruments. (See *Tele-Barometer. Tele-Manometer. Tele-Thermometer.*)

Telepherage.—A system (Fleeming Jenkin) for the conveyance of carriages suspended from electric conductors, and driven by means of electric motors, that take directly from the conductors the current required to energize them.

Two lines are provided, an *up* and a *down* line, that cross each other at regular intervals. Each line is in segments, and the alternate segments are insulated from each other, but are connected electrically by cross pieces on the supporting posts. In this way the line shown in Fig. 382, is obtained.

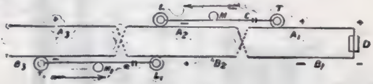


Fig. 382.

The two lines are maintained at a difference of potential by a dynamo-electric machine at D, Fig. 382. As the train at L T, or L′ T′, is of such a length as to come into contact with two different segments at the same time, it receives a current sufficient to run the motor connected with it, the current being received through a conductor joining a pair of wheels that are insulated from the truck.

The general arrangement of the line is shown in the annexed Fig. 381.

Telephone.—An apparatus for the electric transmission of articulate speech.

The articulating telephone, though first brought into public use by Bell, was invented by Reis, in Germany, in 1861. In America, after very protracted litigation, Bell has been decided

legally to be the first inventor, but scientific men very generally recognize the principles of the invention to be fully anticipated by the earlier instruments of Reis. Bell, however, is justly entitled to credit for his *improvements* in the Reis apparatus.

In Bell's *Magneto-Electric Telephone*, the transmitting and receiving instruments are identical. A coil C, of insulated wire connected with the line, is placed on a core of magnetized steel, mounted opposite the centre of a circular diaphragm of thin sheet iron, rigidly supported at its edges.

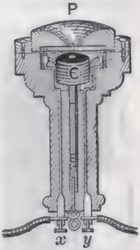


Fig. 377.

In transmitting, the message is spoken into the mouth-piece at one end, as at D, in Fig. 378, and the to-and-fro motions thus imparted to the metallic diaphragm attached to the mouth-piece P, produce *induction currents* in the *coil* C, on the magnet M. (See *Induction, Electro Magnetic.*) These impulses, passing over the main line E L, produce similar movements in the diaphragm P′, of the receiving instrument, at D′, and thus causes it to reproduce the message, in articulate sounds, to one listening at the receiving instrument. A ground circuit is shown in the figure, as usually employed in practice.

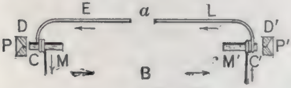


Fig. 378.

A magneto-telephone constitutes in reality a magneto-electric machine, driven or propelled by the voice of the speaker, in which the currents so produced instead of being commuted are employed uncommuted to reproduce the uttered speech.

In actual practice this instrument is replaced by the *electro-magnetic telephone*, in which the to-and-fro motions of the

transmitting diaphragm are caused to vary the resistance of a *button of carbon*, or a *variable contact-transmitter* similar to that employed by Reis in some of his instruments. The variable resistance is placed in the circuit of a battery, so that on speaking into the transmitter, electric impulses are sent over the line and are received by a telephone with a *magnet core* provided with a coil in the main line circuit.

The telephone is arranged for actual commercial use in the United States in the manner shown in Fig. 379.

Telephone, Electro-Capillary ———A telephone in which the movements of the transmitting diaphragm produce currents by means of variations in the electro-motive forces of the contact surfaces of liquids in capillary tubes. (See *Electro Capillary Phenomena.*)

Fig. 379.

In Breguet's telephone both the transmitting and the receiving instruments are similar in construction and operate by means of electro-capillary phenomena. A vertical capillary tube communicates at its upper end with an air space below a diaphragm, and at its lower end with a mercury surface on which rests a layer of acidulated water. A line wire connects the mercury reservoirs of the transmitting and receiving instruments, the remainder of the circuit being formed by another wire connecting the mercury near the upper parts of the two vertical tubes.

The alterations in the contact surfaces at the transmitting end produced by the movements of the diaphragm, cause electric impulses that produce similar movements of the diaphragm at the receiving end.

Telephone, Electro-Motographic ——— or Edison's Electro-Chemical Telephone.—A telephone in

which the receiver consists of a diaphragm of mica or other elastic material operated on the principle of the *electro-motograph.*

A straight lever, which forms part of the line circuit is rigidly attached at one end to the centre of the receiving diaphragm and rests near its other end on the moistened surface of a chalk cylinder, maintained in rotation by suitable mechanical means. Electric impulses being sent into the line by the voice of a speaker talking at a transmitter of ordinary construction, produce slipping movements of the cylinder that reproduce in the receiving diaphragm articulate speech.

Telephonic Exchange.—(See *Exchange, Telephonic.*)

Telephonic Joints of Wire.—(See *Joints, Telegraphic.*)

Telephote or Pherope.—An apparatus for the telegraphic transmission of pictures through the action of light on selenium. (See *Telephotography.*)

Telephotography.—A system for *fac-simile transmission* by means of dots and lines transmitted by means of a continuous current whose intensity is varied by a transmitting instrument, containing a *selenium resistance.* (See *Telegraph, Fac-Simile. Selenium Resistance.*)

The transmitter consists of a dark box, mounted on an axis, so as to be capable of a sidewise motion. The picture to be transmitted is thrown continuously on the face of the box by any lantern projection apparatus, and a small opening containing a selenium resistance receives the alternations of light and shade, and transmits the same as variations in the strength of the otherwise continuous current in the circuit of which the selenium resistance is placed. The picture is received at the other end on a sheet of chemically prepared paper moved synchronously with the transmitting box.

Telescope, Reading ———— —A telescope employed in electric measurements, for reading the deflections of the galvanometer.

A mirror, suspended above the needle on the same fibre that holds the needle, reflects a spot of light on a scale by which the amount of deflection is indicated. (See *Galvanometer, Mirror.*)

A form of *reading telescope* is shown in Fig. 380. An illumined scale M, receives the spot of light reflected from the mirror attached to the galvanometer suspension, and the deflection is observed in the mirror by the telescope F.

Teleseme.—A self-registering hotel annunciator, by means of which a dial operated in a room, indicates on the annunciator the article or service required.

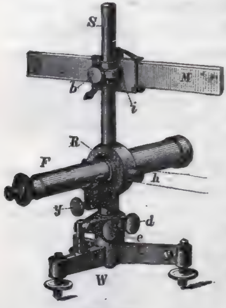


Fig. 380.

Tele-Thermometer, Electric —— —An electric recording thermometer for indicating and recording temperature at a distance.

Temperature Alarm.—(See *Alarm, Fire, etc.*)

Temperature, Effects of —— on Electric Resistance. —(See *Resistance, Effects of Temperature on.*)

Tension, Electric —— — A term often loosely applied to signify *electro-motive force, dielectric stress, difference of potential.*

This term is now very generally abandoned.

Terrestrial Magnetism.—(See *Magnetism Terrestrial.*)

Testing, Methods of —— —(See *Measurements, Electric.*)

Therm.—A heat-unit recently proposed by the British Association.

A therm is the amount of heat required to raise the temper-

ature of one gramme of pure water at the temperature of its maximum density one degree centigrade. (See *Calorie.*)

Thermo-Electric Battery.—(See *Battery, Thermo-Electric.*)

Thermo-Electric Couple.—Two dissimilar metals joined so as to produce thermo-electric currents through differences of temperature.

Thermo-Electric Diagram.—(See *Diagram, Thermo-Electric.*)

Thermo-Electric Inversion.—An inversion of the thermo-electric power of a couple at certain temperatures (See *Diagram, Thermo-Electric.*)

Thermo-Electricity.—Electricity produced by differences of temperature at the junctions of dissimilar metals.

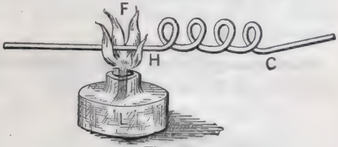


Fig. 381.

If a bar of antimony is soldered to a bar of bismuth, and their free ends connected by means of a galvanometer, the application of heat to the junction, so as to raise its temperature above the rest of the circuit, will produce a current *across* the *junction* from the bismuth to the antimony, (against the alphabet, or from B to A). If, the junction be cooled below the rest of the circuit, a current is produced across the junction from the antimony to the bismuth, (with the alphabet, or from A to B). These currents are called *thermo-electric currents,* and are proportional to the differences of temperature.

Even the same metal, in different physical states or conditions, such as a wire, part of which is straight and the remainder bent into a spiral as at H C, Fig. 381, if heated at F by the flame of a lamp will show a current developed in it.

The same thing may also be shown by placing a cylinder of bismuth J, Fig. 382, in a gap in a hollow rectangle of copper A B, inside of which a magnetic needle M is supported.

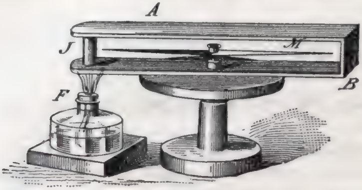


Fig. 382.

The rectangle of copper being placed in the magnetic meridian, on heating the junction by the flame of a lamp F, the needle will be deflected by a current produced by the difference of temperature.

Thermo-Electric Pile, Differential ——— —(See *Differential Thermo-Electric Pile.*)

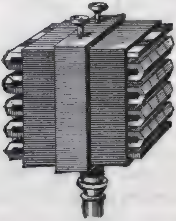


Fig. 383.

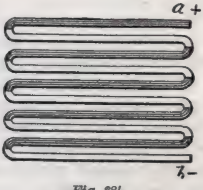


Fig. 384.

Thermo-Electric Pile or Battery.—A number of separate thermo-electric couples, united in series, so as to form a single thermo-electric source.

Figs. 383, and 384, show Nobili's Thermo-Pile, in which a number of bismuth-antimony thermo-electric couples are connected in a continuous series, as shown in Fig. 386, and insulated from one another, except at their junctions, and packed in a metallic box, and supported as shown in Fig. 385. The free terminals of the series are connected to binding posts. Differences of temperature between the two faces of the pile, where the junctions are exposed, result in a current whose difference of potential is equal to the sum of the differences of potential of all the thermo-electric couples.

A careful inspection of the drawing will show that the junctions are formed successively at *opposite* faces of the pile, so that if the junctions be numbered successively, the *even junctions* will come at one face, and the *odd junctions* at the other. This is necessary in order to permit all the thermo-electric couples to *add* their differences of potential; for, if,

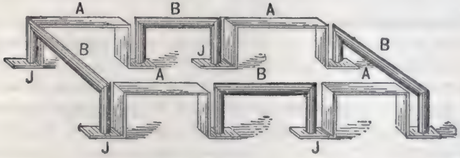


Fig. 385.

as in Fig. 385, a *thermo-electric chain* be formed, no currents will result from equally heating any two consecutive junctions J J, of the metals A and B, since the electro-motive forces so produced oppose each other.

Thermo piles have been constructed by Clamond of couples of iron and an alloy of zinc and antimony, of sufficient power to produce a voltaic arc whose illuminating power equalled 40 carcel burners. Many practical difficulties exist which will have to be surmounted before such piles can be employed as commercial electric sources.

Thermo-Electric Power.—(See *Power, Thermo-Electric.*)

Thermo-Electric Series.—A list of metals so arranged, according to their thermo-electric powers, that each metal in the series is electro-positive to any metal lower in the list.

Thermo-Electro-Motive Force.—Electro-motive force, or difference of potential, produced at thermo-electric junctions by differences of temperature.

Thermometer, Electric ——— or Thermo-Electrometer.—A device for determining the effects of an electric discharge by the movements of a liquid column on the expansion of a confined mass of air through which the discharge is passed.

Thermometer Scale, Centigrade ——.—(See *Centigrade Scale.*)

Thermometer Scale, Fahrenheit ——.—(See *Fahrenheit Scale.*)

Thermophone.—Any instrument by means of which sounds are produced by the absorption of radiant energy. (See *Photophon*

A telephone has been constructed in which the motions of the receiving diaphragm are effected by the expansions and contractions of a thin metallic wire connected to its centre and placed in the circuit of the main line.

Thermostat.—An instrument for automatically indicating the existence of a given temperature by the closing of an electric circuit through the expansion of a solid or liquid.

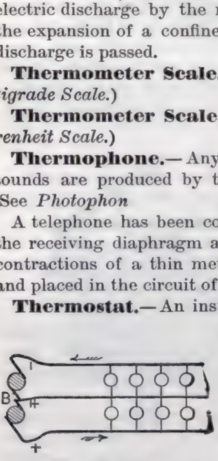


Fig. 386.

Thermostats are used in systems of automatic fire telegraphy, and in systems of automatic temperature regulation.

Three-Wire System.—A system of electric distribution, invented by Edison, in which three wires are employed,

In this system three conductors are connected to a source of electric energy, Fig. 386, and the difference of potential between the central and the two outer conductors is always maintained the same. The lamps or other electro-receptive devices are placed in multiple arc between either branch, and so distributed that the current in each branch is the same. When such a balance is established no current flows through the central or *neutral* conductor. But when that balance is disturbed the surplus current in one branch is taken up by the central conductor. This system effects considerable economy in the weight of wire required.

Thunder.—A loud noise accompanying a lightning discharge.

Thunder is due to the sudden rush of the surrounding air to fill the vacuous space accompanying the disruptive discharge of a cloud. This space is caused by the condensation of the vapor formed on the passage of the discharge through drops of rain or moisture in the air, as well as by the expansion of the air itself.

Thunder-Storms, Geographical Distribution of ——.—(See *Storms, Thunder, Geographical Distribution of.*)

Tick, Magnetic. ——.—A faint metallic click heard on the magnetization and demagnetization of a magnetizable substance. (See *Magnetic Tick.*)

Time Ball, Electric ——.—A ball, supported in a prominent position on a tall pole, and caused to fall at the exact hour of noon, or at any other predetermined time, for the purpose of thus giving the exact time to an entire neighborhood.

The release of the ball is effected by the closing of an electric circuit, either automatically, or through the agency of an observer.

Time Cut-Outs, Automatic. —— ——.—Automatic *cut-outs* arranged on storage batteries to cut them in or out of the circuit of the charging source, at predetermined times.

Time Telegraphy.—(See *Telegraphy, Time. Clocks, Electric.*)

Tongs, Discharging —— —(See *Discharging Rods.*)

Top, Induction —— —(See *Induction, Top.*)

Torpedo, Electric —— —(See *Ray, Electric.*)

Torsion Balance.—(See *Balance, Torsion.*)

Torsion Galvanometer.—(See *Galvanometer, Torsion.*)

Total or Dead Earth.—(See *Earths.*)

Touch, Single, Separate or Double——Methods of Magnetization by.—(See *Magnetization, Methods of.*)

Tourmaline.—A mineral consisting of natural silicates and borates of alumina, lime, iron, etc., possessing *pyro-electric properties.* (See *Pyro-Electricity.*)

Tower, Electric. —— —A high tower provided for the support of a number of electric arc lamps, employed in systems of general illumination.

Tower, System of Electric Lighting.—The lighting of extended areas by means of arc lights placed on the top of tall towers.

The tower-system of electric illumination is only applicable to wide, open spaces, since otherwise objectionable shadows are apt to be formed.

Train Signaling.—(See *Telegraphy, Inductive.*)

Transmission of Energy.—(See *Energy, Transmission of.*)

Transmitters, Electric —— —Various electric apparatus employed in transmitting or sending the electric impulses over a telegraph line.

In most telegraphic systems, the transmitting apparatus consists of various forms of keys for interrupting or varying the current. In the telephone the transmitter consists of a diaphragm operated by the voice of the speaker. (See *Telegraph. Telephone.*)

Transformer or Converter.—(See *Converter or Transformer.*)

Treatment, Hydro-Carbon ——— of Carbons.—(See *Flashing Carbons, Process for.*)

Trigonometry.—That branch of mathematical science which treats of the methods of determining the values of the angles or sides of a triangle.

There are in every triangle three sides and three angles. If any three of these parts are given, except the three angles, the values of the remaining parts can be determined by means of trigonometry, by what is called the *solution* of the triangle.

Trigonometrical Functions.—Certain quantities, the values of which are dependent on the length of the arcs subtended by angles, which are taken for the measures of the arcs instead of the arcs themselves.

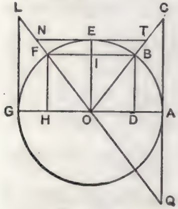


Fig. 387.

The trigonometrical functions are the *sine*, the *co-sine*, the *tangent*, the *co-tangent*, the *secant*, and the *co-secant*. These are generally abreviated, thus, viz. : *sin, cos, tan, cot, sec,* and *co-sec.*

The Sine of an angle, or arc, is the perpendicular distance from one extremity of the arc to the diameter passing through the other extremity.

Thus in Fig. 387, B D, is the sine of the angle B O A, or of the arc, B A.

The *Cosine* of an angle, or arc, is that part of the diameter which lies between the foot of the sine and the centre. Thus D O, is the cosine of the angle B O A, or of the arc B A.

The cosine of an arc is equal to the sine of its complement. Thus E O B or B E, the *complement* of B A, has for its sine I B, which is equal to O D. (See *Complement of Angle.*)

If the arc is greater than a right angle, or 90°, such, for

instance, as the angle T O G, or the arc B E F G, B D is its sine. This is also the sine of B O A, or of B A, which is the supplement of T O G, or B E F G. Hence the sine of an arc is equal to the sine of its supplement.

The same is true of the cosine.

The *Tangent* of an angle, or arc, is a straight line touching the arc at one extremity, drawn perpendicular to the diameter at one end of the arc, and limited by a straight line connecting the centre of the circle and the other end of the arc. Thus C A is the tangent of the angle B O A, or the arc B A.

The *Co-tangent* of an angle, or arc, is equal to the tangent of its complement, thus E T, is the co-tangent of the angle, B O A, or the arc B A.

The *tangent* of an angle, or arc, is equal to the tangent of its supplement. Thus A C, is the tangent of the angle B O A, or the arc B A. It is also equal to the tangent of the angle B O G, or the arc B E F G, the corresponding supplement of the angle B O A, or of the arc B A.

The *Secant* of an angle, or arc, is the straight line drawn from the centre of the circle through one extremity of the arc and limited by the tangent passing through the other extremity. Thus O C is the secant of the angle B O A, or of the arc B A.

The secant of an arc is equal to the secant of its supplement.

The *Co-secant* of an angle, or arc, is equal to the secant of its complement.

Thus E T is the co-secant of the angle B O A, or of the arc B A.

It will be observed that the *co-sine*, the *co-tangent* and the *co-secant* are respectively the sine, tangent, and secant of the complement of the arc, or in other words, the *complement-sine*, the *complement-tangent*, and the *complement-secant*.

Trolleys.—Rolling contacts that move over the overhead lines provided for a line of electric railway cars, and carry off

the current required to drive the motor car. (See *Sled Plow.*)

Tubes, Geissler ——— —(See *Geissler Tubes.*)

Tubes of Force.—(See *Force, Tubes of.*)

Tubes of Induction.—See *Force, Tubes of.*)

Tubes, Mercury ——— —Vacuous glass tubes in which a flash of light is produced by the fall of a small quantity of mercury placed inside it.

The light is caused by the electricity produced by the friction of the mercury in falling against the sides of a spiral glass tube placed inside the vacuous tube.

Tubes, Plücker ——— —(See *PlückerTubes.*)

Tubes, Stratification ——— —(See *Stratification Tubes.*)

Type-Printing Telegraph.—(See *Telegraph Printing.*)

Typewriter, Electric ——— ——— —A type-writing machine in which the keys are intended to make the contacts only of the circuits of electro magnets, by the attractions of the armatures of which the movements of the type levers required for the work of printing are effected.

Electric typewriters secure a uniformity of impression that is impossible to obtain with hand worked machines; they also greatly lessen the mechanical labor of writing.—(See *Dynamograph.*)

Ultra Gaseous Matter.—A term sometimes applied to radiant matter.—(See *Matter, Radiant.*)

Underground Conductors. — Electric conductors placed underground by actual burial, or by passing them through underground *conduits* or *subways.*

Underground conductors, though less unsightly than the ordinary aerial conductors, require to be laid with unusual care to render them equally safe, since, when contacts do occur, all

the wires in the same conduit are apt to be simultaneously affected, thus spreading the danger in many different directions. They are, however, less liable to danger arising from accidental crosses or contacts.

Undulatory Currents.—(See *Currents, Undulatory.*)

Uniform Magnetic Field.—A field traversed by the same number of lines of magnetic force per unit of area of cross section of the field.—(See *Fields, Magnetic.*)

Uniform Potential.—A potential that does not vary.

An electric source is said to generate a uniform potential when it maintains a constant difference of potential at the terminals.

Unipolar Induction.—A term sometimes applied to the induction that occurs when a conductor is so moved through a magnetic field as to continuously cut its lines of force.

If the conducting wire A B C, Fig. 388, be rotated (in a direction towards the observer) around the pole N of a magnet, it will continuously cut its lines of magnetic force and will therefore produce a continuous current in the direction of the arrows. The end A is supported in a recess in N, while the end near C slides on a projection on the middle of the magnet. Unipolar dynamos operate on the continuous cutting of lines of magnetic force.

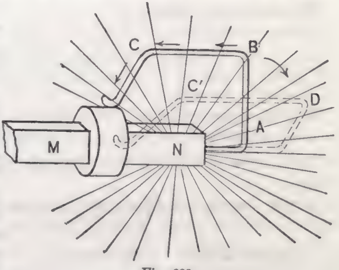


Fig. 388.

Strictly speaking there is no such thing as a unipolar dynamo, or unipolar induction, since a single magnetic pole can-

not exist by itself. Continuous cutting of lines of magnetic force, however, can exist and produces, unlike the ordinary bi-polar induction, a continuous current.

Unit Angle.—(See *Angular Velocity.*)

Unit, B. A. ——— —The British Association unit of resistance or ohm.—(See *Ohm.*)

Unit of Acceleration.—(See *Acceleration, Unit of.*)

Unit of Activity.—(See *Activity, Unit of.*)

Unit Differnce of Potential or Electro-Motive Force.—Such a difference of potential between two points that requires the expenditure of one *erg* of work to bring a unit of positive electricity from one of these points to the other, against the electric force. (See *Erg.*)

Unit Jar.—(See *Jar, Unit.*)

Unit of Current, Jacobi's ——— —A current which passed through a voltameter will liberate in one minute a cubic centimetre of oxygen and hydrogen at 0° C. and 760 m. m. barometric pressure.

One Jacobi's Unit of Current equals $\frac{1}{10.32}$ Weber per second. (Obsolete.)

Unit of Heat, New.—(See *Therm.*)

Unit of Mass.—(See *Mass, Unit of.*)

Unit of Power.—(See *Power, Unit of.*)

Unit of Pressure, New ——— —(See *Barad.*)

Unit of Resistance, Jacobi's ——— —The electric resistance of 25 feet of a certain copper wire weighing 345 grains.

Another unit of electric resistance proposed by Jacobi was the resistance of a copper wire one metre in length and one millimetre in diameter.

Unit of Resistance, Matthiessen's ——— —The resistance of one statute mile of pure annealed copper wire $\frac{1}{8}$ of an inch in diameter at 15.6° C.

Unit of Resistance, Varley's —— —The resistance of one statute mile of a special copper wire $\frac{1}{16}$ of an inch in diameter.

Varley's unit was afterwards adjusted by him to equal 25 Siemens mercury units.

Unit of Resistance.—Such a resistance that unit difference of potential is required to cause a current of unit strength to pass.

Unit Quantity of Electricity.—The quantity of electricity conveyed by unit current per second.

Unit of Supply, Electrical —— —A unit-provisionally adopted in England by the Board of Trade, equal to 1,000 ampères flowing for one hour under an electro-motive force of one volt.

This would, of course, equal 1,000 watt hours, and would be the same as 100 ampères flowing for ten hours under one volt.

One unit of electrical supply is equal to 1.34 actual horse power expended for one hour, and will feed 13.4 Swan lamps of 21 candle power for one hour. It is equal in illuminating power in Swan lamps, to the light produced by 100 cubic feet of gas consumed in twenty 14-candle burners in one hour.

Unit Strength of Current.—Such a strength of current that when passed through a circuit one centimetre in length, arranged in an arc of one centimetre radius, will exert a force of one dyne on a unit magnet pole placed at the centre.

Unit of Velocity, New —— The Kine—(See *Kine.*)

Units C. G. S. —— —The centimetre-gramme-second units.—(See *Units, Fundamental.*)

Units, Derived —— —Various units obtained or derived from the fundamental units of Length, L, Mass, M, and Time, T.

The derived units and their dimensions are as follows :

Area, L^2.—The Square Centimetre.

Volume, L^3.—The Cubic Centimetre.

Velocity, V.—Unit Distance traversed in Unit Time, or

$$V = \frac{L}{T} \quad (1)$$

Acceleration, A.—The rate of change which will produce a change of velocity of one centimetre per second.

$$A = \frac{V}{T} \quad (2)$$

Substituting in equation (2) the value of V in equation (1), we have,

$$A = \frac{\frac{L}{T}}{\frac{T}{1}} = \frac{L}{T^2} \quad (3)$$

Force, F.—The *Dyne*, or the force required to act on unit mass in order to impart to it unit velocity.

$$F = M \times A \quad (4)$$

Substituting the value of A derived from equation (2), we have,

$$F = M \times \frac{V}{T}.$$

Substituting the value of V derived from equation (1), we have,

$$F = \frac{M}{T} \times \frac{L}{T} = \frac{ML}{T^2} \quad (5)$$

Work or Energy, W.—The *Erg*, or the work done in overcoming unit force through unit distance.

$$W = F \times L = \frac{ML}{T^2} \times L = \frac{ML^2}{T^2}.$$

Power, P.—The Unit Rate of Doing Work.

$$P = \frac{W}{T} = \frac{\frac{ML^2}{T^2}}{\frac{T}{1}} = \frac{ML^2}{T^3} \cdot \quad (6)$$

Units, Electro-Magnetic —— —A system of units derived from the C. G. S. units, employed in electro-magnetic measurements.

Units, Electro-Magnetic, Dimensions of ———

Current strength = Intensity of Field × Length $= \frac{\sqrt{ML}}{T}$.

Quantity = Current × Time = $\sqrt{M \times L}$.

Potential. Dif. of Pot. / Electro-motive force } $= \frac{\text{Work}}{\text{Quantity}} = \frac{\sqrt{M \times L^3}}{T^2}$.

$$\text{Resistance} = \frac{\text{Electro-motive force}}{\text{Current}} = \frac{L}{T} \cdot$$

$$\text{Capacity} = \frac{\text{Quantity}}{\text{Potential}} = \frac{T^2}{L} \cdot$$

Units, Electrostatic —— —Units based on the force exerted between two equal quantities of electricity.

Two systems of electric units are derived from the C. G. S. system, viz., the *Electrostatic* and the *Electromagnetic*. These units are based respectively on the force exerted between two quantities of electricity, and between two magnet poles.

The electrostatic units embrace the units of *Quantity*, *Potential*, and *Capacity*. No particular names have as yet been adopted for these units.

Unit of Quantity.—That quantity of electricity which will repel an equal quantity of the same kind of electricity placed

at a distance of one centimetre from it with the force of one dyne.

Electrostatic potential, or power of doing electrostatic work, is measured in units of work, or ergs.

Unit Difference of Potential.—Such a difference of potential between two points as requires the expenditure of one *erg* of work to bring up a unit of positive electricity from one point to the other against the electric force.

Unit of Capacity—Such a capacity of a conductor as requires a charge of one unit of electricity to raise it to unit potential.

Specific Inductive Capacity.—The ratio between the inductive capacity of a substance and that of air, measured under precisely similar conditions.

The specific inductive capacity is obtained by comparing the capacity of a condenser filled with the particular substance, and the capacity of the same condenser when filled with air. The specific inductive capacity of air is taken as unity.

Units, Electrostatic, Dimensions of.—

$$\text{Quantity} = \sqrt{\text{force} \times (\text{distance})^2} = \sqrt{F \times L^2} = \frac{M^{\frac{1}{2}} L^{\frac{3}{2}}}{T}$$

$$= \frac{\sqrt{M \times L^3}}{T} \, .$$

$$\text{Current} = \frac{\text{Quantity}}{\text{Time}} = \frac{M^{\frac{1}{2}} L^{\frac{3}{2}}}{T^2} = \frac{\sqrt{M \times L^3}}{T^2} \, .$$

$$\text{Potential} = \frac{\text{Work}}{\text{Quantity}} = \frac{M^{\frac{1}{2}} L^{\frac{1}{2}}}{T} = \frac{\sqrt{M \times L}}{T} \, .$$

$$\text{Resistance} = \frac{\text{Potential}}{\text{Current}} = L^{-1}\, T = \frac{T}{L} \, .$$

$$\text{Capacity} = \frac{\text{Quantity}}{\text{Potential}} = L \, .$$

Specific Inductive Capacity $= \frac{\text{One Quantity}}{\text{Another Quantity}} =$ A simple ratio or number.

Electro-motive Intensity $= \frac{\text{Force}}{\text{Quantity}} = M^{\frac{1}{2}}\, L^{\frac{1}{2}}\, T^{-1} = \frac{\sqrt{M \times L}}{T}$

The fractional and negative exponents used above are merely convenient methods of expressing the contraction of roots, and division by the quantity represented by the negative exponent.

Units, Fundamental ——.—The units of length, time, and mass, to which all other quantities can be referred.

The unit of length is now generally taken as the *Centimetre ;* the unit of time as the *Second ;* and the unit of mass as the *Gramme.* These form a system of measurement known as the *centimetre-gramme-second* system, or the C. G. S. system, or absolute system.

The dimensions of the fundamental units, are designated thus:

Length = L.
Mass = M.
Time = T.

Units of Heat.—(See *Heat, Units.*)

Units, Magnetic.—Units based on the force exerted between two magnet poles.

Unit Strength of Magnetic Pole.—Such magnetic strength of pole that repels another magnetic pole of equal strength placed at unit distance with unit force, or one dyne.

Magnetic Potential.—Power of doing work possessed by a magnet pole.

Magnetic Potential is measured, like electrostatic potential, in units of work, or in ergs.

Magnetic Potential, Unit Difference of.—Such a difference of magnetic potential between two points that requires the expenditure of one erg of work to bring up a magnetic pole of unit strength towards a like pole.

Unit Intensity of Magnetic Field.—Such an intensity of magnetic field as acts on a north-seeking pole of unit strength with the force of one dyne.

Units, Magnetic, Dimensions of—— —

$$\left.\begin{array}{l}\text{Strength of Pole, or}\\ \text{Quantity of Magnetism}\end{array}\right\} = \sqrt{\text{Force} \times (\text{Distance})^2} = \frac{\sqrt{M\,L^3}}{T}.$$

$$\text{Magnetic Potential} = \frac{\text{Work}}{\text{Strength of pole}} = \frac{\sqrt{M \times L}}{T}.$$

$$\text{Intensity of field} = \frac{\text{Force}}{\text{Strength of pole}} = \frac{\sqrt{M}}{L^2 \times T}.$$

Units, Practical —— —Multiples or fractions of the absolute or centimetre-gramme-second units.

The practical units have been introduced because the absolute units are either too small or too large for actual use.

Electro-motive Force.—The *Volt* = 100,000,000 C. G. S. or absolute units, that is, 10^8 absolute units of resistance. (See *Volt.*)

Resistance.—The *Ohm* = 1,000,000,000 absolute units of resistance, or 10^9 absolute units. (See *Ohm.*)

Current.—The *Ampère* = $\frac{1}{10}$ Absolute Unit of Current. (See *Ampère.*)

Quantity.—The *Coulomb* = $\frac{1}{10}$ Absolute Unit of Quantity, of the electro magnetic system.—(See *Coulomb.*)

Capacity.—The *Farad* = $\frac{1}{1{,}000{,}000{,}000}$ Absolute Unit of Capacity, or 10^9 units of capacity. (See *Farad.*)

Universal Discharger.—(See *Discharger, Universal.*)

Vacuum, Absolute ——.—A space from which all traces of residual gas have been removed.

A term sometimes loosely applied to a high vacuum. It is doubtful whether an absolute vacuum is attainable by any physical means.

Vacuum, High ——.—Such a vacuum that the length of the mean free path of the molecules of the residual atmosphere is equal to, or exceeds, the dimensions of the containing vessel. (See *Layer, Crookes'.*)

Vacuum, Low or Partial —— ——.—Such a vacuum that the mean free path of the molecules of the residual gas is small, as compared with the dimensions of the containing vessel. (See *Tubes, Geissler.*)

In a high vacuum, groups of molecules can move across the containing vessel without meeting other groups of molecules. In a low vacuum, such a group of molecules would be broken up by collision against other groups before reaching the other side of the vessel.

Vacuum Pumps.—(See *Pumps.*)

Vacuum Tubes.—(See *Tubes, Vacuum.*)

Valency.—The worth or value of the chemical atoms as regards their power of displacing other atoms in chemical compounds. (See *Atomicity.*)

The worth, or valency, of oxygen is twice as great as that of hydrogen, since one atom of oxygen is able to replace two hydrogen atoms in chemical combinations.

Valve-Burner, Electric Argand ——.—(See *Argand Valve-Burner, Electric.*)

Valve, Electric ——.—An electrically controlled or operated valve.

In systems of *electro-pneumatic signals,* gaseous or liquid pressure controlled by electrically operated valves, is employed to move signals, ring bells, control water and air valves, or to perform other similar work.

Vapor Globe of Incandescent Lamp.—A glass globe surrounding the chamber of an incandescent electric lamp, for the purpose of enabling the lamp to be safely used in explosive atmospheres, or to permit the lamp to be exposed in places where water is liable to fall on it.

Such a vapor globe is shown in Fig. 389.

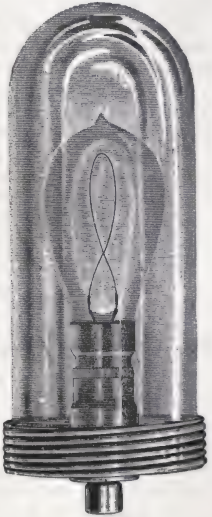


Fig. 389.

Variable State of Charge of Telegraph Line. — (See *State, Variable.*)

Variation, Annual, Diurnal, Irregular, Secular.————(See *Declination, Magnetic, Varieties of.*)

Variation Chart. — (See *Chart, Variation.*)

Variation Compass.—(See *Compass, Variation.*)

Variation Needle. — (See *Needle, Declination.*)

Variations, Magnetic————(See *Magnetic Variations.*)

Varnish, Electric ——— or Insulating Varnish.—A varnish formed of any good insulating material.

Shellac dissolved in alcohol, applied to a thoroughly dried surface and afterwards hardened by baking, forms an excellent varnish.

Vegetation, Effects of Electricity on ——— —Most vegetable fibres contract on the passage of an electric current through them when in the living plant.

Velocity, Angular ——— —(See *Angular Velocity.*)

Velocity of Discharge.—The time required for the passage of a discharge through a conductor, as compared with its length.

By means of a rapidly revolving mirror Wheatstone measured the velocity at which the discharge of a Leyden jar passed through half a mile of copper wire as 288,000 miles per second.

The velocity of discharge through long conductors or cables is much lessened by the *capacity* of the cable and the effects of *induction*, etc. (See *Retardation.*)

Velocity Ratio.—A remarkable ratio, in the nature of a *velocity*, that exists between the ratio of the electro-static and the electro-magnetic values of the electric units.

This ratio will be understood from the comparison of the following units:

$$Quantity = \frac{M^{\frac{1}{2}}\ L^{\frac{3}{2}}\ T^{-1}}{M^{\frac{1}{2}}\ L^{\frac{1}{2}}} = \frac{L}{T} = V \ .$$

Here the value of the ratio, viz., the *length* divided by the *time*, is clearly in the nature of a velocity, for $V = \frac{L}{T}$.

$$Potential = \frac{M^{\frac{1}{2}}\ L^{\frac{1}{2}}\ T^{-1}}{M^{\frac{1}{2}}\ L^{\frac{3}{2}}\ T^{-2}} = \frac{T}{L} = \frac{1}{V} \ .$$

$$Capacity = \frac{L}{L^{-1}\ T^{2}} = \frac{L^{2}}{T^{2}} = V^{2} \ .$$

$$Resistance = \frac{L^{-1}\ T}{L\ \ T^{-1}} = \frac{T^{2}}{L^{2}} = \frac{1}{V^{2}} \ .$$

A remarkable similarity exists between the value of the *velocity* expressed in C. G. S. units, and the velocity of light, which is of great significance in the *electro-magnetic theory of light*. (See *Light, Electro-Magnetic Theory of.*)

The velocity of light is, say, 2.9992×10^{10} centim. per second.

The velocity ratio, v, is 2.9800×10^{10} centimetres per second.

Ventilation of Armature.—Devices for the free passage of air or other fluid through the armature of a dynamo-electric machine in order to prevent its over-heating. (See *Dynamo-Electric Machine, Armature, Ventilation of.*)

Vernier.—A device for the approximately accurate measurement of smaller differences of length than can be readily detected by the eye.

There are a variety of vernier scales in use.

Vernier Wire Gauge. (See *Wire Gauge, Vernier.*)

Vibration.—A to-and-fro motion of the particles of an elastic medium. (See *Waves.*)

Vibrations, Sympathetic ———(See *Sympathetic Vibrations.*)

Vis-Viva.—The energy stored in a moving body. Hence, the measure of the amount of work that must be performed in order to bring a moving body to rest.

The vis-viva $= \frac{M\ V}{2}$ ·

This term is gradually becoming obsolete.

Vitreous Electricity.—A term formerly employed to indicate positive electricity.

It was formerly believed that the friction of glass with other bodies always produced positive electricity.

The term is now replaced by *positive electricity.* (See *Resinous Electricity.*)

Volcanic Lightning. (See *Lightning, Volcanic.*)

Volt.—The practical unit of electro-motive force.

Such an electro-motive as is induced in a conductor which cuts lines of magnetic force at the rate of 100,000,000 per sec.

Such an electro-motive force as would cause a *current* of one *ampère* to flow against the *resistance* of one *ohm.*

Such an electro-motive force as would charge a condenser of the *capacity* of one *farad* with a *quantity* of electricity equal to one *coulomb.*

Volt-Ampère.—The *watt* or unit of electric power. (See *Power, Electric.*)

Volt-Meter Galvanometer.—(See *Galvanometer, Volt-Meter.*)

Voltaic Alternatives.—(See *Alternatives, Voltaic.*)

Voltaic Arc.—(See *Arc, Voltaic.*)

Voltaic Battery.—(See *Battery, Voltaic.*)

Voltaic Cell.—An electric source consisting of a voltaic *couple* and one or two *electrolytes.* (See *Cell, Voltaic.*)

Voltaic Couple.—Two dissimilar metals, or a metal and a metalloid, capable of acting as an electric source, when dipped in an electrolyte, or capable of producing a difference of electric potential by mere contact. (See *Couple, Voltaic.*)

Liquids and gases are capable of acting as voltaic couples.

Voltaic Element.—One of the two substances that form a voltaic couple. (See *Couple, Voltaic.*)

Voltaic Electricity.—Electricity produced by the agency of a voltaic cell or battery.

Electricity is the same thing, or phase of energy, by whatever source it is produced.

Voltaic or Current Induction.—A variety of electro-dynamic induction produced by circuits on themselves, or in neighboring circuits. (See *Induction, Electro-Dynamic.*)

Voltameter.—An electrolytic cell employed for measuring the strength of the current passing through it by the amount of chemical decomposition effected in a given time.

Various electrolytes are employed in voltameters, such as aqueous solutions of sulphuric acid, copper sulphate, or other metallic salts..

In the water voltameter shown in Fig. 390, the battery terminals are connected with *platinum* electrodes immersed in water slightly acidulated with sulphuric acid, and placed

inside glass tubes, also filled with acidulated water. On the passage of the current, hydrogen appears at the *kathode*, and oxygen at the *anode*, in *nearly* the proportion of two volumes to one. (See *Ozone*.)

Fig. 390.

In the case of sulphuric acid (*hydrogen sulphate*) the decomposition would appear to be as follows :

$$H_2\,S\,O_4 = H_2 + SO_4.$$

The hydrogen appears at the electro negative terminal, or *kathode*. The SO_4 appears at the electro positive terminal or *anode*, but, combines with one molecule of water, thus, $SO_4 + H_2\,O = H_2\,SO_4 + O$, gaseous oxygen being given off at the anode.

Voltameters are not as well suited as galvanometers for the measurement of electric currents, because a certain electromotive force must be reached before electrolysis is effected.

The voltameter in reality measures the coulombs, and, therefore, is valuable as a current measurer only when the current is constant.

Coulomb-meter would, therefor, be the preferable term.

Then, again, time is required to produce the results, and considerable difficulty is experienced in maintaining the cur-

rent strength constant, either on account of variations in the electro-motive force of the source, or of variations in the resistance of the voltameter.

Voltameter, Siemens' Differential ——— ————A form of voltameter employed by Sir Wm. Siemens for determining the resistance of the platinum spiral in his electric pyrometer. (See *Pyrometer, Electric.*)

Two separate voltameter tubes provided with platinum electrodes and filled with dilute sulphuric acid, are provided with carefully graduated tubes to determine the volume of the decomposed gases. (See *Voltameter.*)

A current from a battery is divided by a suitable commutator into two circuits connected respectively with the two voltameter tubes. In one of these circuits a known resistance is placed, in the other the resistance to be measured, *i. e.*, the platinum coil used in the electric pyrometer.

Edison's electric meter consists of a *Voltameter*. (See *Meter, Electric.*)

Volt-ammeter.—A variety of galvanometer capable of directly measuring both the difference of potential and the ampères.

Volt-Coulomb.—The unit of electric work. The Joule. (See *Joule.*)

Voltmeter.—A galvanometer for measuring the electromotive force, or difference of potential, between any two points in a circuit. (See *Galvanometer.*)

Vulcanized Fibre.—A variety of insulating material suitable for purposes not requiring the highest insulation.

Vulcanized fibre is, however, seriously affected by long exposure to moisture.

Vulcanite or Ebonite.—A variety of vulcanized rubber extensively used in the construction of electric apparatus.

Though an excellent insulator, vulcanite will lose its insulating properties by condensing a film of moisture on its sur-

face. This can be best removed by the careful application of heat.

The surface is very liable to become covered by a film of sulphuric acid due to the gradual oxidation of the sulphur. Mere friction will not remove this film, but it may be removed by washing with distilled water. A thick coating of varnish will obviate this last defect.

Watchman's Electric Register.—A device for permanently recording the time of a watchman's visit to each locality he is required to visit at stated intervals.

These registers are of a variety of forms. They consist, however, in general, of a drum or disc of paper driven by clockwork, on which a mark is made by a stylus or pencil, operated by the closing of a circuit by a push button pressed or key turned by the watchman at each station.

Water Battery.—(See *Battery, Water.*)

Water Dropping Accumulator.— (See *Accumulator, Water Dropping.*)

Water, Electrolysis of ——— — The decomposition of water by the passage through it of an electric current.

When pure, water does not appear to conduct electricity; it is therefore not quite certain that pure water can be electrolytically decomposed. The addition of a small quantity of sulphuric acid, or of a metallic salt, however, renders its electrolysis readily accomplished.

Water-Level Alarm.—(See *Alarm, Liquid Level.*)

Water Pyrometer.—(See *Pyrometer, Water.*)

Watches, Demagnetization of ——— — Procsesses for readily removing magnetism from watches.

The demagnetization of watches can be readily effected by a method proposed by J. J. Wright. The watch is held by its chain and slowly lowered to the bottom of a hollow conical coil of wire, and then slowly withdrawn from the coil.

The wire is wound on the coil, as shown in Fig. 391, in the shape of a cone, viz., with a single turn at the top, and gradually increasing in number of turns towards the bottom.

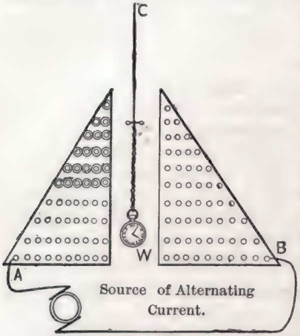


Fig. 391.

The conical coil is connected with a source of rapidly alternating currents.

As the watch is lowered in the coil, it becomes gradually magnetized more and more powerfully with opposite polarities, thus completely reversing and removing any polarity it previously possessed. As it is now slowly raised from out the hollow cone, this magnetization becomes less and less, until, if removed from the conical coil while *high above its apex*, all sensible traces of magnetism will have disappeared.

Watt.—The *volt-ampère*, or unit of electric work. (See *Work, Electric, Unit of.*)

Watt-Hour, Watt-Minute, Watt-Second.—Units of work.

Terms employed to indicate the expenditure of an electrical power of one *watt, for an hour, minute,* or *second.*

Watt-Meter.—A galvanometer by means of which the simultaneous measurement of the difference of potential and the current passing is rendered possible.

The *Watt-Meter* consists of two coils of insulated wire, one coarse and the other fine, placed at right angles to each other

as in the *ohm-meter*, only instead of the currents acting on a suspended magnetic needle, they act on each other, as in the electro-dynamometer.

Waves, Amplitude of —— —(See *Amplitude of Waves.*)

Waves, Electric —— —(See *Oscillations, Electric.*)

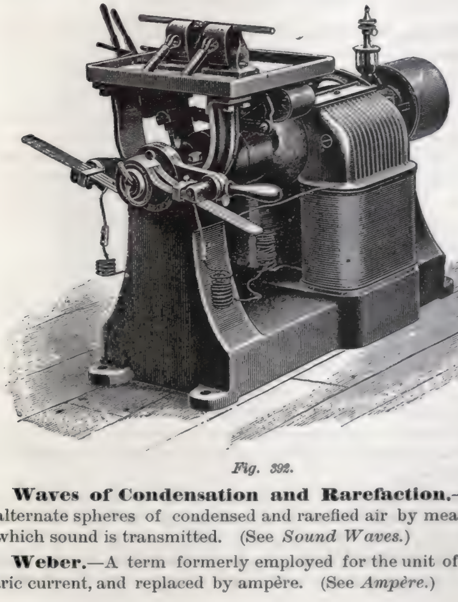


Fig. 392.

Waves of Condensation and Rarefaction.—The alternate spheres of condensed and rarefied air by means of which sound is transmitted. (See *Sound Waves.*)

Weber.—A term formerly employed for the unit of electric current, and replaced by ampère. (See *Ampère.*)

Weber.—A term proposed by Clausius and Siemens for a magnetic pole of unit strength but not adopted.

This same term was also employed to designate the unit strength of current. Now replaced by the term ampère.

Weight, Atomic ——— —(See *Atomic Weight.*)

Weight, Breaking —— of Telegraph Wires.—(See *Breaking Weight of Telegraph Wires.*)

Welding, Electric ——— —Effecting the welding union of metals by heat of an electric origin.

In the process of Elihu Thomson, the metals are heated to electric incandescence by currents obtained from inverted induction coils, and are subsequently pressed or hammered together.

Fig. 392, shows the Thomson apparatus for the Direct System of Electric Welding. The dynamo is combined with the welding apparatus. The armature contains two separate windings; one of fine wire, in series with the field magnet coils, and another of very low resistance, being formed of a U-shaped bars of copper. No commutation is used, the alternating currents being well adapted for heating purposes. The terminals of these poles are, therefore, directly connected to the clamps that hold the bar to the welder.

Fig. 393, shows the apparatus for the Thomson Indirect System of Electric Welding. This system is applicable to heavy work, and cases where more than one welding machine is operated by the current from a single dynamo.

In this case a high tension current is converted into the large welding current employed by means of a suitably proportioned transformer.

The welding process is the same in either system, and consists essentially in leading the welding current into the pieces to be united near their points of junction when brought into firm end contact. As the current is lead across the junction the temperature rises sufficiently to soften the metal, when

the pieces are firmly pressed together by the motion of the clamps or holders.

In the process of Benardos and Olzewski, the heat of the voltaic arc is employed for a somewhat similar process.

Wheatstone's Balance.—(See *Balance, Wheatstone's.*)

Wheel, Barlow's or Sturgeon's ——— ———— —(See *Disc, Faraday's.*)

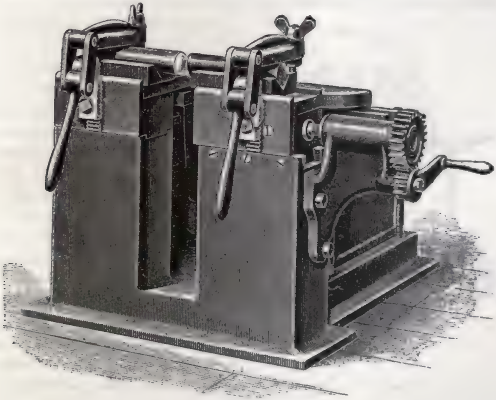


Fig. 393.

Wheel, Phonic ——— —See *Phonic Wheel.*)

Wheel, Reaction ——— —(See *Reaction Wheel.*)

Whirl, Electric ——— —A term employed to indicate the circular direction of the lines of magnetic force surrounding a conductor conveying an electric current. See *Field Electro Magnetic,*)

Whistle, Automatic Electric Steam —— —A steam whistle, employed on foggy days in some systems of railway signals, when the visual signals can not be seen, in which the passage of the steam through the whistle is automatically obtained by the closing of an electric contact, or the passage of the locomotive over a certain part of the track.

Wimshurst Electrical Machine.—A form of convection electric machine invented by Wimshurst.

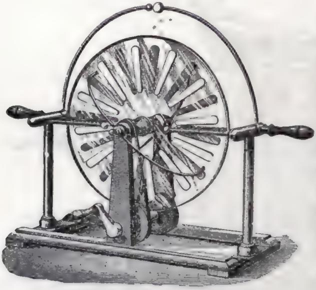


Fig. 394.

Like the Holtz machine, the Wimshurst machine is a convection induction machine. It is, however, more efficient in action, and will probably soon supersede the former machine. The Wimshurst machine consists of two shellac-varnished glass plates, that are rapidly rotated in opposite directions. Thin metallic strips are placed on the outside of each of the plates, in the radial positions shown in Fig. 394. These metal strips act both as *inductors* and *carriers;* the carrier of one plate acting as an inductor to the other plate.

Two curved brass rods, terminating in fine wire brushes that touch the plates, are placed as shown, one at the front of the plate, and one at the back, at right angles to each other. Pairs of conductors, connected together, provided with collecting points, are placed diametrically opposite each other, as shown. Sliding conductors, terminated with metallic balls, are provided for discharging the conductors. Leyden jars

the inner coatings of which are connected with the two discharging rods, and the outer coatings together may be employed in this as in the Holtz machine.

The exact action of this machine is not thoroughly understood.

Wind, Electric ——— —The convection stream of air particles produced at the extremities of points attached to the surface of charged, insulated conductors. (See *Convection, Electric. Flier, Electric.*)

Fig 395.

Windage of Dynamo.—A term proposed for the air gap between the armature and the pole pieces of a dynamo.

Winding, Compound ——— —(See *Compound Wound Dynamo-Electric Machine.*)

Windings, Ampère ————— —(See *Turns, Ampère.*)

Windings, Bi-Filar —— of Coils.—(See *Bi-Filar Windings of Coils.*)

Wire Gauge.—A device for accurately measuring the diameter of a wire.

The *round wire gauge*, shown in Fig. 395, is very generally used for telegraph lines. Notches of varying widths, cut in the edges of a circular plate of tempered steel, serve to approximately measure the diameter of a wire, the side of the wire being passed through the slots. Numbers, indicating the different sizes of the wire, are affixed to each of the openings.

Wire Gauge, Vernier or Micrometer —— .—A gauge employed for accurately measuring the diameter of a wire in thousandths of an inch, based on the principle of the *vernier* or *micrometer*. See Fig. 396.

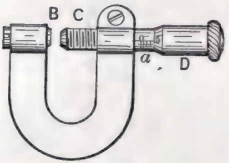


Fig. 396.

The wire to be measured is placed between a fixed support B, and the end C, of a long movable screw, which accurately fits a threaded tube *a*. A thimble D, provided with a milled head fits over the screw C, and is attached to the upper part. The lower circumference of D, is divided into a scale of 20 equal parts. The tube *a*, is graduated into divisions equal to the pitch of the screw. Every fifth of these divisions is marked as a larger division.

The principle of the operation of the gauge is as follows: Suppose the screw has 50 threads to the inch, the pitch of the screw, or the distance between two contiguous threads, is, therefore, $\frac{1}{50}$, or .02 of an inch.

One complete turn of the screw will therefore advance the sleeve D, over the scale *a*, the .02 inch. If the screw is only moved through one of the 20 parts marked on the end of the thimble or sleeve parts, or the $\frac{1}{20}$ of a complete turn, the end C advances towards B the $\frac{1}{20}$ of $\frac{1}{50}$, *i. e.*, $\frac{1}{1000}$ or .001 inch.

Suppose, now, a wire is placed between B and C, and the screw advanced until it fairly fills the space between them, and the reading shows two of the larger divisions on the scale *a*, three of the smaller ones, and three on the end of the sleeve **D.** Then

2 larger divisions of scale *a*	=	0.2 inch
3 smaller divisions of scale *a*	=	.06
3 divisions on circular scale on D	=	.006
Diameter of wire	=	0.266

Serious inconvenience has arisen in practice from the numerous arbitrary numbers or sizes of wires employed by different manufacturers. These differences are gradually leading to the abandonment of arbitrary sizes for wires, and employing in place thereof, the diameters directly in *inches* or *thousands* of an inch.

Wire, Grounded ——— — (See *Ground or Earth.*)

Wire, Insulated ——— —Wire covered with any insulating material.

Cotton and silk are generally employed for insulating purposes, either alone, or in connection with various gums, resins, or other materials, which are plastic when heated, but which solidify on cooling. India rubber, caoutchouc, and various mixtures and compounds are also employed for the same purpose.

For most of the purposes of line wires, high insulating powers, combined with a low specific inductive capacity, is required in the insulating materials.

For overhead wires a waterproof covering is necessary. In the neighborhood of combustible materials, some fireproof covering is desirable.

Wires, Conductibility and Sizes of ——— —. The following tables give the resistance, size, weight per foot, etc., of wire according to some of the principal wire gauges.

Number, Diameter, Weight, Length, and Resistance of Pure Copper Wire.

AMERICAN GAUGE.

	Diam.	Weight Sp. Gr. -8.889.		Length.	Resistance of Pure Copper at 70° Fahrenheit.		
No.	Inches.	Grs. per Ft.	Lbs. per 1000 feet.	Ft. per Lb.	Ohms per 1000 Ft.	Feet per Ohm.	Ohms per Lb.
0000	.460	4475.33	639.33	1.56	.051	19605.69	.0000798
000	.40964	3549.07	507.01	1.97	.064	15547.87	.000127
00	.36480	2814.62	402.09	2.49	.081	12330.36	.000202
0	.32495	2233.28	319.04	3.13	.102	9783.63	.000320
1	.28930	1770.13	252.88	3.95	.129	7754.66	.00051
2	.25763	1403.79	200.54	4.99	.163	6149.78	.000811
3	.22942	1113.20	159.03	6.29	.205	4876.73	.001289
4	.20431	882.85	126.12	7.93	.259	3867.62	.00205
5	.18194	700.10	100.01	10.00	.326	3067.06	.00326
6	.16202	555.20	79.32	12.61	.411	2432.22	.00518
7	.14428	440.27	62.90	15.90	.519	1928.75	.00824
8	.12849	349.18	49.88	20.05	.654	1529.69	.01311
9	.11443	276.94	39.56	25.28	.824	1213.22	.02083
10	.10189	219.57	31.37	31.88	1.040	961.91	.03314
11	.09074	174.15	24.88	40.20	1.311	762.93	.05269
12	.08081	138.11	19.73	50.69	1.653	605.03	.08377
13	.07196	109.52	15.65	63.91	2.084	479.80	.13321
14	.06408	86.86	12.41	80.59	2.628	380.51	.2118
15	.05706	68.88	9.84	101.63	3.314	301.75	.3368
16	.05082	54.63	7.81	128.14	4.179	239.32	.5555
17	.04525	43.32	6.19	161.59	5.269	189.78	.8515
18	.04030	34.35	4.91	203.76	6.645	150.50	1.3539
19	.03589	26.49	3.78	264.26	8.617	116.05	2.2772
20	.03196	21.61	3.09	324.00	10.566	94.65	3.423
21	.02846	17.13	2.45	408.56	13.323	75.06	5.443
22	.025347	13.59	1.94	515.15	16.799	59.53	8.654
23	.022571	10.77	1.54	649.66	21.185	47.20	13.763
24	.0201	8.54	1.22	819.21	26.713	37.43	21.885
25	.0179	6.78	.97	1032.96	33.684	29.69	34.795
26	.01594	5.37	.77	1302.61	42.477	23.54	55.331
27	.014195	4.26	.61	1642.55	53.563	18.68	87.979
28	.012641	3.38	.48	2071.22	67.542	14.81	139.893
29	.011257	2.68	.38	2611.82	85.170	11.74	222.449
30	.010025	2.13	.30	3293.97	107.391	9.31	353.742
31	.008928	1.69	.24	4152.22	135.402	7.39	562.221
32	.00795	1.34	.19	5236.66	170.765	5.86	894.242
33	.00708	1.06	.15	6602.71	215.312	4.64	1421.646
34	.0063	.84	.12	8328.30	271.583	3.68	2261.82
35	.00561	.67	.10	10501.35	342.413	2.92	3596.104
36	.005	.53	.08	13238.83	431.712	2.32	5715.36
37	.00445	.42	.06	16691.06	544.287	1.84	9084.71
38	.003965	.34	.05	20854.65	686.511	1.46	14320.26
39	.003531	.27	.04	26302.23	865.046	1.16	22752.6
40	.003144	.21	.03	33175.54	1091.865	.92	36223.59

Table Showing the Difference between Wire Gauges.

No.	London.	Stubs.	Brown & Sharpe's.
0000	.454	.454	.460
000	.425	.425	.40964
00	.380	.380	.36480
0	.340	.340	.32495
1	.300	.300	.28930
2	.284	.284	.25763
3	.259	.259	.22942
4	.238	.238	.20431
5	.220	.220	.18194
6	.203	.203	.16202
7	.180	.180	.14428
8	.165	.165	.12849
9	.148	.148	.11443
10	.134	.134	.10189
11	.120	.120	.09074
12	.109	.109	.08081
13	.095	.095	.07196
14	.083	.083	.06408
15	.072	.072	.05706
16	.065	.065	.05082
17	.058	.058	.04525
18	.049	.049	.04030
19	.040	.042	.03589
20	.035	.035	.03196
21	.0315	.032	.02846
22	.0295	.028	.025347
23	.027	.025	.022571
24	.025	.022	.0201
25	.023	.020	.0179
26	.0205	.018	.01594
27	.01875	.016	.014195
28	.0165	.014	.012641
29	.0155	.013	.011257
30	.01375	.012	.010025
31	.01225	.010	.008928
32	.01125	.009	.00795
33	.01025	.008	.00708
34	.0095	.007	.0063
35	.009	.005	.00561
36	.0075	.004	.005
37	.0065		.00445
38	.00575		.003965
39	.005		.003531
40	.0045		.003144

New Legal Standard Wire Gauge (English).

Tables of Sizes, Weights, Lengths and Breaking Strains of Iron Wire.

Size on Wire Gauge.	Diameter.		Section-al area in sq. inches.	Weight of		Length of Cwt.	Breaking strains		Size on Wire Gauge
	Inch.	Mille-metres.		100 yards.	Mile.		Anneal-ed.	Bright.	
				Lbs.	Lbs.	Yards.	Lbs.	Lbs.	
7/0	.500	12.7	.1963	193.4	3404	58	10470	15700	7/0
6/0	.464	11.8	.1691	166.5	2930	67	9017	13525	6/0
5/0	.432	11.	.1466	144.4	2541	78	7814	11725	5/0
4/0	.400	10.2	.1257	123.8	2179	91	6702	10052	4/0
3/0	.372	9.4	.1087	107.1	1885	105	5796	8694	3/0
2/0	.348	8.8	.0951	93.7	1649	120	5072	7608	2/0
1/0	.324	8.2	.0824	81.2	1429	138	4397	6595	1/0
1	.300	7.6	.0707	69.9	1225	161	3770	5655	1
2	.276	7.	.0598	58.9	1037	190	3190	4785	2
3	.252	6.4	.0499	49.1	864	228	2660	3990	3
4	.232	5.9	.0423	41.6	732	269	2254	3381	4
5	.212	5.4	.0353	34.8	612	322	1883	2824	5
6	.192	4.9	.0290	28.0	502	393	1544	2316	6
7	.176	4.5	.0243	24.	422	467	1298	1946	7
8	.160	4.1	.0201	19.8	348	566	1072	1608	8
9	.144	3.7	.0163	16.	282	700	869	1303	9
10	.128	3.3	.0129	12.7	223	882	687	1030	10
11	.116	3.	.0106	10.4	183	1077	564	845	11
12	.104	2.6	.0085	8.4	148	1333	454	680	12
13	.092	2.3	.0066	6.5	114	1723	355	532	13
14	.080	2.	.0050	5.	88	2240	268	402	14
15	.072	1.8	.0041	4.	70	2800	218	326	15
16	.064	1.6	.0032	3.2	56	3500	172	257	16
17	.056	1.4	.0025	2.4	42	4667	131	197	17
18	.048	1.2	.0018	1.8	32	6222	97	145	18
19	.040	1.	.0013	1.2	21	9333	67	100	19
20	.036	.9	.0010	1.	18	11200	55	82	20

(Issued by the Iron and Steel Wire Mfrs. Association.)

Wires, Cross——— — (See *Cross, Electric.*)

Wires, Crossing. (See *Crossing Wires.*)

Wood's Button Repeater.—(See *Repeater, Telegraphic.*)

Work, Electric.—The Joule. (See *Joule.*)

Work, Electric, Unit of —— —— — The *volt-coulomb* or *joule.* (See *Volt-Coulomb. Joule.*)

Work, Unit of —— — The *erg.* (See *Erg.*)

Yokes of Electro Magnet.—The solid cross pieces of iron that join the ends of the field magnet coils of dynamo electric machines, or of electro magnets generally.

Zero Methods.—(See *Null Methods.*)

Zero Potential.—The potential that would exist at an infinite distance from any electrified body.

In practice, the potential of the earth is regarded as the zero potential. (See *Potential, Zero.*)

Zig-zag Lightning.—Forked lightning, (See *Lightning, Zig-zag.*)

Zinc, Amalgamation of —— —The covering or amalgamation of zinc with a layer of mercury.

To amalgamate a plate of zinc, its surface is first thoroughly cleaned by immersing the plate in dilute sulphuric acid of about one part of acid to ten or twelve parts of water, A few drops of mercury are then rubbed over its surface, thus coating it with a bright metallic film of zinc amalgam. Care must be taken not to use too much mercury, since the zinc plate will thus be rendered brittle.

The necessity for amalgamating the zinc arises from the loss of energy through *local action*, on ordinary plates.

The action of the amalgam appears to be to cover the surface of the zinc plate with a layer of chemically pure zinc. On the polarization of the battery on closing its circuit the zinc ends of the zinc-amalgam are turned towards the negative plate, thus in effect producing a plate of chemically pure zinc.

Zincode of Voltaic Cell.—A term formerly employed to indicate the zinc terminal or electrode of a voltaic cell.

The *negative electrode* or *kathode*, are preferable terms.

Zone, Polar ——— —A term proposed by De Watteville for the zone or region surrounding the therapeutic electrode applied to the human body for electric treatment.

Zone, Peripolar ——— —A term proposed by De Watteville for the zone or region surrounding the polar zone on the body of a patient under electro therapeutic treatment.

Zinc Sender.—A device employed in telegraphic circuits, in which, in order to counteract the retardation produced by the charge given to the line, a momentary reverse current is sent into the line after each signal.

A zinc sender generally consists of a low resistance Siemens relay introduced between the line and the front contact of the signaling key.

THE END.

APPENDIX.

Balance or Neutral-Wire Ampère Meter.—An ampère meter placed in the circuit of the neutral wire, in a three-wire system of electric distribution, for the purpose of showing the excess of current passing over one side of the system as compared with the other side, when the central wire is no longer neutral.

Balanced Metallic Circuit.—A metallic circuit, the two sides of which have similar electrical properties.

Banked Battery.—(See *Battery, Banked.*)

Battery, Banked.—A term sometimes applied to a battery from which a number of separate circuits are supplied with current.

The term, banked battery, is sometimes applied to a multiple-arc connected battery.

Bed-Piece of Dynamo Electric Machine.—The frame on which a dynamo is supported.

The bed-piece is sometimes called the dynamo frame.

Bell, Night.——— —(See *Night Bell.*)

Board, Cross-Connecting.——— —(See *Cross Connecting Board.*)

Box, Cable.——— —(See *Cable Box.*)

Box, Junction.——— —(See *Junction Box.*)

Branch.—A term applied to any principal distributing conductor from which outlets are taken, or taps made.

Break-Down Switch.—A special switch, employed in small three-wire systems, for connecting the positive and negative bus-wires in such a manner as to permit the system to be supplied with current from the dynamo in use on one side of the system only.

Bridges.—Heavy copper wires suitably shaped for connecting the dynamo electric machines in a station to the bus-rods or wires.

Bug.—A term originally limited to quadruplex telegraphy to designate any fault in the operation of the apparatus.

This term is now employed, to a limited extent, for faults in the operation of electric apparatus in general.

Bug-Trap.—Any device employed to overcome the "bug" in quadruplex telegraphy.

Bus-Rods or Wires.—Heavy copper rods employed in a station, to which all the generating dynamos are connected and from which the current passes to the different points of the distribution system over the feeders.

Cable Box.—A receptacle provided for holding and securing the terminals of a cable, or underground conductor.

Cable Laid-Up in Layers.—A term applied to a cable, all the wires of which are in layers.

Cable Laid-Up in Reversed Layers.—A term applied to a cable in which the conductors, in alternate layers, are twisted in opposite directions.

Cable Laid-Up in Twisted Pairs.—A term applied to a cable in which every pair of wires is twisted together.

Calling-Drop.—An annunciator drop employed to indicate to the operator in a telegraphic or telephonic system that one subscriber wishes to be connected with another.

Calling-Wire.—A wire employed in a telegraphic or telephonic system, by means of which a subscriber communicates with the central office, or one central office communicates with another.

Cam, Listening.——— —(See *Listening Cam.*)

Capacity of a Cable.—The electrostatic capacity of one conductor of a cable as compared with the capacity of the remainder of the conductors grounded.

Centre of Distribution.—In a system of multiple-distribution, a place where branch cut-outs and switches are placed in order to control communication therewith.

Climbers and Straps.—Devices employed by linemen for climbing wooden telegraph poles.

Colombin.—A name applied to the insulator between the parallel carbons of the Jablochkoff candle, consisting of a mixture of sulphate of barytes and sulphate of lime.

Commutating Transformers, Distribution by ——— —(See *System of Electrical Distribution by Commutating Transformers.*)

Condensers, System of Alternate Current Distribution by Means of——— —(See *System of Alternate Current Distribution by Means of Condensers.*)

Condensers, System of Continuous Current Distribution by Means of——— —(See *System of Continuous Current Distribution by Means of Condensers.*)

Contraplex Telegraphy.—A name given to a special system of duplex telegraphy.

Cross Arm.—A horizontal beam attached to a pole for the support of telegraph, electric light and other electric wires.

Cross Connecting Board.—In a system of telegraphic or telephonic communication, a board to which the line terminals are run before entering the switchboard, so as to readily place any subscriber on any desired section of the switchboard.

Cross Connection, Telephonic——— —A device employed in systems of telephonic communication for the purpose of lessening the bad effects of induction, in which equal lengths of adjacent parallel wires are alternately crossed so as to alternately occupy the opposite sides of the circuit.

Cross-Talk.—In telephony an indistinctness in the speech transmitted over any circuit due to this circuit receiving,

either by accidental contacts or by induction, the speech transmitted over neighboring circuits.

Curb, Double ——— —(See *Double Curb.*)

Curb Signaling.—In cable telegraphy a system for avoiding the effects of retardation by rapidly discharging the cable before another electric impulse is sent into it, not by connecting it to earth, but by reversing the battery and then connecting to earth before beginning the next signal.

Curb Signaling, Double Curb ——— — In curb signaling, a method by which the cable, after connection with the battery for sending a signal, is subjected to a reverse battery, but instead of being put to earth after this connection as in single curb signaling, the battery is again reversed and connected to earth.

The time during which the cable is connected to the reversed battery before being put to earth, that is, the time during which it receives the positive and negative currents may be made of any suitable duration.

Curb Signaling, Single Curb ——— —In curb signaling, a method by which the cable after connection with the battery for sending a signal, is subjected to a reverse battery current and then put to earth before again being connected to the battery for sending the next signal.

Cut-out, Duplex ——— —(See *Duplex Cut-out.*)

Decalescence.—A term proposed by Prof. Elihu Thomson for the absorption of sensible heat which occurs at a certain point during the heating of a bar of steel.

Decalescence will thus be observed to be the reverse of recalescence, which is the phenomenon of the emission of sensible heat at a certain point during the cooling of a heated bar of steel. (See *Recalescence.*)

Distribution of Continuous Currents by Means of Condensers.—(See *System of Continuous Current Distribution by Means of Condensers.*)

Double Curb.—An instrument invented by Sir William Thomson, employed in curb signaling, by means of which the signals are made and the curb, either single or double, in any required proportion, is applied automatically.

Double Curb Signaling.—(See *Curb Signaling, Double Curb.*)

Double Plug.—A plug so constructed that when inserted in a spring-jack it makes two connections, one at its point and one at its shank. (See *Spring Jack.*)

Double Trolley System of Electric Railroads.—A system of electric railroad propulsion, in which a double trolley is employed to take the the driving current from the overhead wires.

The double trolley system differs from the single trolley system in that it employs no earth return. The parallel wires also avoid the effects of injurious induction in neighboring telegraph or telephone wires.

Duplex Cut-out.—A cut-out so arranged that when one box is fused or melted by an abnormal current, another can be immediately substituted for it.

Electric Thermo Call.—An instrument for sounding an alarm when the temperature rises above, or falls below, a fixed point.

In one form of this instrument a needle is moved over a dial by a simple thermic device and rings a bell when the temperature for which it has been set is attained. The thermo-call is applicable to the regulation of the temperature of dwellings, incubators, hot houses, breweries, drying rooms, etc.

Feeder.—One of the conducting wires or channels through which the current is distributed to the main conductors.

Feeder-Switch.—The switch employed for connecting or disconnecting each conductor of a feeder from the bus-bars in a central station.

Feeder-Equalizer.—An adjustable resistance placed in the circuit of a feeder for the purpose of regulating the difference of potential at the junction box.

Fire Balls.—A term sometimes applied to globular lightning. (See *Lightning, Globular.*)

Force de Cheval.—The French term for horse power.

The force de cheval is equal to 32,560 foot pounds per minute.

Frame of Dynamo Electric Machine.—The bed piece that supports a dynamo electric machine.

The frame is sometimes called the dynamo bed piece.

Graduators.—Devices, generally electro magnets, inserted in a circuit so as to obtain the makes and breaks, required in a system of telegraphy, so gradually that they fail to influence the diaphragm of a telephone placed in the same circuit, and thus to permit a simultaneous telegraphic and telephonic transmission over the same wire.

Ground Detector.—In a system of incandescent lamp distribution, a device, placed in the central station, for showing by the candle power of a lamp, the proximate location of a ground on the system.

Horse Power of Water.—The Indian Government's term for horse power developed by falling water.

The estimate is made by the following simple rule: 15 cubic feet of water falling per second through one foot equals 1 horse power.

House Main.—A term employed in a system of multiple incandescent lamp distribution for the conductor connecting the house service conductors with a centre of distribution.

House-Service Conductor.—A term employed in a system of multiple incandescent lamp distribution for that portion of the circuit which is included between the service cut-out and the centre or centres of distribution, or between this cut-out and one or more points on house mains.

Hysteresis.—Molecular friction to magnetic change of stress.

That property of a medium in virtue of which work is done in changing the direction or intensity of magnetic force among its parts.

Intercrossing.—In a system of telephonic communication, a device for avoiding the disturbing effects of induction by alternately crossing equal sections of the line. (See *Cross-Connections, Telephonic.*)

Joint, Sleeve.——— —(See *Sleeve Joint.*)

Junction Box.—A moisture-proof box provided in a system of underground conductors to receive the terminals of the feeders, and in which connection is made between the feeders and the mains from which the current is distributed to the individual consumer.

Kinetic Theory of Matter.—A theory which assumes that the molecules of matter are in a constant state of motion or vibration towards, or from, one another.

Applying the kinetic theory of matter to gases, the molecules of which have great freedom of motion, the molecules are so far removed from one another as to be but little, if any, influenced by their mutual attractions. They are therefore assumed to move in straight lines with very great velocity until they collide against one another, or against the sides of the containing vessel, when they are reflected and again run in straight lines in a new path.

Leg.—In a system of telephonic exchange, a single wire, where a ground system is used, or two wires where a metallic circuit is employed, for connecting a subscriber with the main switchboard, by means of which the subscriber may be legged or placed directly in circuit with two or more parties.

Legging Key-Board.—A key-board employed for the purpose of legging an operator into the circuit connecting two or more subscribers.

Lines, Overhead.——— —(See *Overhead Lines.*)

Listening Cam.—In a telephonic exchange system a metallic cam by means of which the operator is placed in circuit with a subscriber.

Main Feeder.—(See *Standard or Main Feeder.*)

Main, House ——— —(See *House Main.*)

Mains, Street ——— —(See *Street Mains.*)

Matter, Kinetic Theory of ——— —(See *Kinetic Theory of Matter.*)

Motor-Generators. — Dynamo-electric generators in which the power required to drive the dynamo is obtained from an electric current.

Motor generators are used in systems of electrical distribution for the purpose of changing the potential of the current. They consist of dynamos, the armatures of which are furnished with two separate windings, of fine and of coarse wire respectively. One of these, generally the fine wire, receives the driving or motor current, usually of high potential, and the other, the coarse wire, furnishes the current used, usually of low potential.

Motor-Generators, System of Electric Distribution by ——— —(See *System of Electric Distribution by Motor-Generators.*)

Neutral Relay Armature.—A term applied in contradistinction to a polarized relay armature, in which the relay armature, consisting of a piece of soft iron wire, closes a local circuit whenever its electro-magnet receives an impulse over the main line. (See *Polarized Armature.*)

Neutral Wire.—The middle wire of a three-wire system of electric distribution.

Night Bell.—In a telephone exchange, a bell switched into connection with the shunted circuit of an annunciator

case, and provided for calling the attention of the night operator by its constant ringing to the falling of a drop.

Outlet.—In a system of incandescent lamp distribution the point of attachment for a socket in a fixture.

Overhead Line.—A term applied to telegraph, telephone, and electric light or power lines that run overhead, in contradistinction to similar lines placed underground.

Phantom Wires.—A term applied to the additional circuits or wires obtained in any single wire or conductor by the use of some multiplex telegraphic system. (See *Telegraphy, Multiplex. Synchronous Multiplex System of Telegraphy.*)

Phonoplex Telegraphy.—A system of telegraphic transmission in which pulsatory currents, superposed on the ordinary Morse currents, actuate a modified telephonic receiver, and thus permit the simultaneous transmission of several separate messages over a single wire without interference.

Platymeter.—An instrument invented by Sir William Thomson for comparing the capacities of two condensers.

Plugs.—Metallic connections in the shape of plugs for making or breaking circuits by placing them in, or removing them from, metallic sockets connected with the circuits to be made or broken.

Plugging.—Completing a circuit by means of plugs.

Recalescence.—The property, first pointed out by Barrett, possessed by steel when cooling after being heated to incandescence, of again becoming incandescent after a certain degree of cooling has been effected.

A steel wire heated at the middle or near one end to a bright red, and allowed to cool in a dim light, will be observed to cool until a low red heat is reached, when it will be observed to reheat at some point in the originally heated portion. This re-heating is manifested by a brighter red spot

which moves along the portion originally heated. This reheating is called recalescence, and is due to latent heat (potential energy) which, disappearing when the bar was heated, again becomes sensible (kinetic energy) on cooling.

The temperature at which recalescence takes place is sensibly the temperature at which heated steel regains its magnetizability.

Relay Armature, Neutral —— —(See *Neutral Relay Armature.*)

Service Conductor, House —— —(See *House Service Conductor.*)

Service, Street —— —(See *Street Service.*)

Single Curb Signaling.—(See *Curb Signaling, Single Curb.*)

Sleeve Joint.—A method of joining conducting wires by passing them through tubes and then twisting and soldering.

Stackling a Wire.—Placing an insulator between the two ends of a cut wire.

Standard or Main Feeder.—The main feeder to which the standard pressure indicator is connected, and whose pressure controls the pressure at the ends of all the other feeders.

The term pressure in the above definition is used in the sense of electro-motive force or difference of potential.

Street Mains.—In a system of incandescent lamp distribution the conductors through which the current is distributed from the feeder ends, through cut-outs, to the district to be lighted, and from which service wires are taken.

Street Service.—In a system of incandescent lamp distribution that portion of the circuit which is included between the main and the service cut-out.

Switch, Break Down —— —(See *Break Down Switch.*)

System of Alternate Current Distribution by Means of Condensers.—A system of alternate current distribution in which condensers are employed to transform current charges of high potential received from an alternating current dynamo, to charges of low potential which are fed to the lamps or other electro-receptive devices.

In the system of McElroy the conversion from high to low potential is obtained by making the plates of the condensers charged by the dynamo, or primary plates, smaller than the secondary plates, the ratio of the area of the primary plates to that of the secondary plates being made in accordance with the ratio of conversion desired.

System of Continuous Current Distribution by Means of Condensers.—A system of distribution devised by Doubrava in which a continuous current is conducted to certain points in the line where a device called a "disjunctor" is employed to reverse it periodically and the reversed currents so obtained directly used to charge condensers in the circuit of which induction coils are placed.

The condensers are used to feed incandescent lamps or other electro-receptive devices.

System of Electrical Distribution by Commutating Transformers.—A system of electrical distribution in which motor-generators are used, but neither the armature nor the field magnets are revolved, a special commutator being employed to change the polarity of the magnetic circuits.

System of Electric Distribution by Motor-Generators.—A system of electric distribution in which a continuous current of high potential, distributed over a main line, is employed at the points where its electric energy is to be utilized for driving a motor, which in turn drives a dynamo, the current of which is used to energize the electro-receptive devices.

In another system of motor-generators the motor and dynamo are combined in one machine with a double wound armature, the fine wire coils in which receives the high potential driving current and the coarse wire coils furnish the low potential current used in the distribution circuits.

System of Simultaneous Telegraphy and Telephony over a Single Wire.—A system for the simultaneous transmission of telegraphic and telephonic messages over a single wire.

These systems are based, in general, on the fact that a gradual make and break in a telephone circuit fails to appreciably affect a telephone diaphragm. By the use of graduators the makes and breaks required for the transmission of the telegraphic dispatch are effected so gradually that they fail to appreciably influence the telephone diaphragm and thus permit simultaneous telegraphic and telephonic transmission over a single wire. (See *Graduators.*)

Tailings.—False markings received in systems of automatic telegraphy, due to retardation.

Telegraphy, Contraplex —— —(See *Contraplex Telegraphy.*)

Telegraphy, Phonoplex —— —(See *Phonoplex Telegraphy.*)

Thermo Call, Electric —— —(See *Electric Thermo Call.*)

Thermolysis.—A term applied to the chemical decomposition of a substance by heat.

Thermolysis, or dissociation, is an effect produced by the action of heat somewhat similiar to the effect of electrolysis, or chemical decomposition produced by the passage of an electric current. When a chemical substance is heated, the vibration of its molecules is attended by an inter-atomic vibration of its constituent atoms so that a decomposition ensues. If the temperature is not excessive these liberated

atoms recombine with others which they meet, but at higher temperatures such recombination is impossible and a permanent decomposition ensues, called thermolysis or dissociation.

Torque.—The stress on a shaft due to electro-magnetic action, that is, the turning effort exerted by the armature of a motor, for instance, under the influence of the current. The torque is usually measured in pounds of pull at the end of a radius or arm 1 foot in length.

Transposing.—In a system of telephonic communication a device for avoiding the bad effects of induction by alternately crossing equal consecutive sections of the line. (See *Cross-Connection, Telephonic.*)

Trolley System, Double —— for Electric Railroads.—(See *Double Trolley System of Electric Railroads.*

Trunk Lines.—In a system of telephonic communication lines connecting distant stations and used by a number of subscribers at each end for purposes of intercommunication.

Trunking Switchboard.—A switchboard in which a few subscribers only are connected with the operator, thus enabling him to obtain any other subscriber by means of trunk wires extending to the other sections.

Units and Terms, Proposed New —— —The following units and terms have recently been proposed by Oliver Heaviside, but have not been generally accepted or adopted. These definitions are given in Mr. Heaviside's language.

"*Conductance.*—Capacity for conducting electricity.

"Numerically, the ratio, in absolute measure, of the current strength to the total electro-motive force in a circuit of uniform flow. A quantity with the nature of a slowness or reciprocal to a velocity. The practical unit is called the mho."

"*Conductivity.*—Conductance per unit volume."

"*Elastance.*—Capacity of a dielectric for opposing electric charge or displacement.

"Numerically, the ratio, in absolute measure, of the difference of potential in an electrostatic circuit to the total charge or displacement therein produced. The reciprocal of permittance and a quantity of the inverse nature of a length."

"*Elastivity.*—Elastance per unit volume of dielectric."

"*Impedance.*—Capacity for opposing the variable flow of electricity.

"Numerically, in the absolute measure, the ratio of the total electro-motive force to the current strength at any instant in a circuit of variable flow. A quantity with the nature of a velocity and in any circuit always greater than the resistance."

"*Inductance.*—Capacity for magnetic induction.

"Numerically, in absolute measure, the number of unit lines of magnetic force linked with a circuit traversed by the unit current strength. Sometimes alluded to as the coefficient of self induction. A quantity of the nature of a length."

"*Inductivity.*—Specific capacity for magnetic induction.

"The numerical ratio of the induction in a medium to the induction producing it."

"*Permittance.*—Electrostatic capacity. Capacity of a dielectric for assisting charge or displacement.

"Numerically, the ratio, in absolute measure, of the total charge or displacement in an electrostatic circuit, to the difference of potential producing it. A quantity with the nature of a length."

"*Permittivity.*—The numerical ratio of the permittance of a dielectric to that of air.

"Also known as specific inductive capacity."

"*Reluctance.*—Capacity for opposing magnetic induction.

"Numerically, the ratio, in absolute measure, of the magneto-motive force in a magnetic circuit to the total induction therein produced. A quantity with the nature of the reciprocal of a length. Sometimes described as magnetic resistance."

"*Reluctancy or Reluctivity.*—Reluctance per unit volume.

"Sometimes described as specific magnetic resistance. A numeric, the reciprocal of inductivity."

"*Resistance.*—Capacity for opposing the steady flow of electricity.

"Numerically, in absolute measure, the ratio of the total electro-motive force to the current strength in a circuit of uniform flow. A quantity with the nature of a velocity. The practical unit is called the ohm."

"*Resistivity.*—Resistance per unit volume; sometimes alluded to as specific resistance."

Wire, Neutral ——— —(See *Neutral Wire.*)

Wires, Phantom ——— —(See *Phantom Wires.*)